ASSUMPTION UNIVERSITY (ABAC), BANGKOK

มหาวิทยาลัยอัสสัมชัญ

# A Feasibility Study of the Manufacturing Execution System in the Semiconductor Industry


by

Mr. Anucha Phongsantichai


A Final Report of the Three-Credit Course
CE 6998 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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| Project Title | A Feasibility Study of the Manufacturing Execution System in the Semiconductor Industry |
| Name | Mr. Anucha Phongsantichai |
| Project Advisor | Dr. Chamnong Jungthirapanich |
| Academic Year | November 2003 |

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

Approval Committee:

(Dr. Chamnong Ju !thrapanich)
Dean and Advisor

(Prof.Dr. Srisakdi Charmonman)
Chairman

(Assoc.Prof. Somchai Thayarnyong)
CHE Representative

November 2003

ABSTRACT

This project is conducted as a feasibility study for the administrative system analysis and design of Microchip Technology which is a fully integrated semiconductor manufacturing company, in particular with an emphasis on the manufacturing in Thailand. The possibility of investment is assessed both qualitatively and quantitatively. Problems identification of the existing system and the users' requirement are essential factors in formulating the appropriate solution as the proposed system.

The main purpose of this project is to present the analysis of the current administrative manufacturing system, especially the Integrated Circuit (IC) manufacturing procedure. Thus the Manufacturing Execution System (MES) is designed as a proposed system that is strongly determined to solve the problems occurring in manufacturing areas so as to create a new image by streamlining the working process or paperless, operational management. The proposed system is specified by user requirements.

Nevertheless, the MES can play a major role to many agile manufacturers and the trend of MES progression is being applied to all manufacturing environments, from discrete-part manufacturing to process manufacturing. Each application has its own MES variation, but the concept is the same. Further, the feasibility analysis for the proposed system is a tool to help for decision making of the investment, including pros and cons of MES when the system is installed in manufacturing function at Microchip, Thailand. Gantt chart or project timeline of the proposed system is briefly defined to understand easily in real task. Finally, the beneficial outcome will also be achieved by investing on the recommended system.

ACKNOWLEDGEMENTS

I am indebted to following people and organizations. Without them, this project would not have been possible.

I wish to express sincere gratitude to my advisor, Dr. Chamnong Jungthirapanich, Dean of Graduate School of Computer and Engineering Management. His patient assistance, guidance, and constant encouragement have led me from the project inception to the project completion. Further, I would like to express appreciation to the project committee of Graduate School of Assumption University including Assoc.Prof. Somchai Thayarnyong for his constructive comments and advice throughout the project.

I would like to thank Mr. Robin Ross, project manager of MES implementation team and Mr. Wichest Jamniyom, senior manufacturing engineer. Both are Microchip employees who gave me some useful information for use in the analysis and evaluation process.

Special appreciation is due to my family for their fervent, continuous encouragement and also all my friends: Ms. Thipapan Pandee, Mr. Niti Teerakitti, Mr. Vatha Promlikitchai especially Mr. Mongkol Thatprasertsin and Mr. Vivitawin Krerngkamjornkij who supported me with the scanner machine to complete this project.

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# I. INTRODUCTION

## 1.1 Background of the Project

Over the past few years, the manufacturing companies have implemented large Enterprise Resource Planning (ERP) systems, which have proven to be very effective and efficient. It has been a challenge, since the companies want to easily track product, control process flow, deliver the exact document to a factory floor and retrieve critical data from the manufacturing. These data are required in order to portray an accurate account of the day-to-day product manufacturing operations. The solution is a Manufacturing Execution System (MES).

In the present, many new systems have been developed in order to facilitate manufacturing people satisfaction in their daily activities. The fundamental of new systems is Management Information System (MIS) which integrates with many parts in the operation such as Client and Server application, Information Technology, etc. Because of their efficiency, they have more effects with manufacturing organizations that work for a lot of data transaction and collection.

Manufacturing Execution System (MES) is a system which delivers information enabling the optimization of production activities from order launch to finished goods. MES uses the existing and accurate data to guide, initiate, response to and report on factory activities as they occur. Moreover, MES is of particular value to operational management. The functions include resource allocation and status, dispatching production units, data collection, equipment integration, process flows, operations scheduling, product traceability, and work-in-process (WIP) tracking.

This project is conducted to analyze and improve the manufacturing system of Microchip Technology (Thailand) Co., Ltd.; which has the main roles of Integrated

Circuit (IC) assembly and test, 100% exportation business. Nowadays, there is a large of investment and expansion regarding the semiconductor industry in Asia-Pacific zone that is why most manufacturing suppliers are concentrating on how to improve their working process flow, to retrieve the accurate data, product tracking and paperless system.

Normally this kind of organization has to do a lot of paper work related to product data such as product type, product quantity, machine number, worker ID, etc. even the other supported information such as statistical control process (SPC) data, production throughputs report, yield report, and so on. The existing system is collecting data by manually in each step of operation. An inaccurate data may occur from human error. Hence, MES has to eliminate this error, and reduce the waste of unnecessary documents so that the processes will reduce whole cycle time of the system.

MES provides all the necessary and correct information to operators or assemblers at the correct time. Quality, manufacturing and engineering data are stored in separate databases, are accessible across the network for combined reporting. Aspect of data collection and acquisition, MES provides an interface link to obtain the inter-operational production and parametric data that populate the forms and records that were attached to the production unit. The data may be collected from the factory floor either manually or automatically from equipment in an up-to-the-minute time frame. For the function of production tracking, MES provides the on-line tracking function creates a historical record, as well. This record allows traceability of components and usage of each end product.

Therefore Manufacturing Execution System (MES) is considered to be a proposed system. Because of the semiconductor industry is in a high competitive business, which requires greater productivity and efficiency in nowadays. The MES can rapidly respond to changing conditions and drives effective factory operations.

In addition MES offers the value-added processes, helping manufacturing cycle time reduction and empowering plant operations staff.

## 1.2 Objective of the Project

The objectives of the project are to describe the new methodology of operational management integrated with computer software and also evaluate the possibility of Manufacturing Execution System (MES) to be the proposed system. Furthermore, it will help for operational activities improvement and highly competitive/productive. Finally it will make greater production efficiency and effectiveness.

## 1.3 Scope of the Project

The scope of the project is to study only Microchip Technology (Thailand), especially manufacturing area. Most of functions are manually operated and non value-added activities during transaction process. It analyzes the administration system that collects a lot of information on paper work and improves it. This project would suggest the MES as the proposed system for long term solution and MES in the future.

The project focuses on two major factors that the organization will be impacted; one is aspect of financial factor such as cash flow, capital budgeting etc. Another is operational factor. Nevertheless the project does not present the marketing analysis because of the project almost concentrates only production area of the organization.

# II. LITERATURE REVIEW

This section will propose what MES is, the MES definition, functional model of MES, MES core functions and also support functions. Furthermore it also provides the benefits model of MES, the future for MES and application.

## 2.1 What MES Is

Manufacturing Execution System (MES) has evolved to fill the communication gap between the manufacturing planning system such as MRP, MRPII, ERP, etc. and the control systems used to run any equipment on the shop floor. Previously, these were the tools of production management, along with a lot of printed papers or paper works of information such as statistical process control (SPC), time attendance, receiving report, shipping report, inspection report, and whatever; to accomplish the production task. In the meantime, production determined how to consolidate all the information together but a few problems occurred with this arrangement.

(1) The data was usually late.

(2) The data was rarely reliably correct.

(3) The information was voluminous and difficult to condense.

(4) The information was usually based on another department.

Then there were computer software systems which were developed to help production managers better use this information to execute the manufacturing plan; hence many companies offered solutions for specific areas in manufacturing and called them Manufacturing Execution Systems. For example; SPC has been called an MES. WIP tracking system has been called an MES. Even data collection systems have been called MES. There are many more samples that follow this same name, and leaving most users get confuse.

There is no official definition of MES, but the most inclusive and specific definition might be the following: Manufacturing Execution System (MES) is the on-line integrated computerized system that is the accumulation of the methods and tools used to accomplish production. (McClellan 1997)

Another definition of MES is the system delivers information enabling the optimization of production activities from order launch to finished goods. Using current and accurate data, MES initiates, and reports on plant activities as they occur. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications. (Fraser 1992)

## 2.2 MES Context Model

The MES context model is an overview of the manufacturing execution system that shows the system boundaries, systems overlap and linkage that interact with the system. (Vinhais 1998)

There are five system elements relate and link with MES which consist of Sale and Service Management, Supply Chain Management, Enterprise Resources Planning, Product and Process Engineering and the last one is Controls System. This diagram is shown as Figure 2.1.

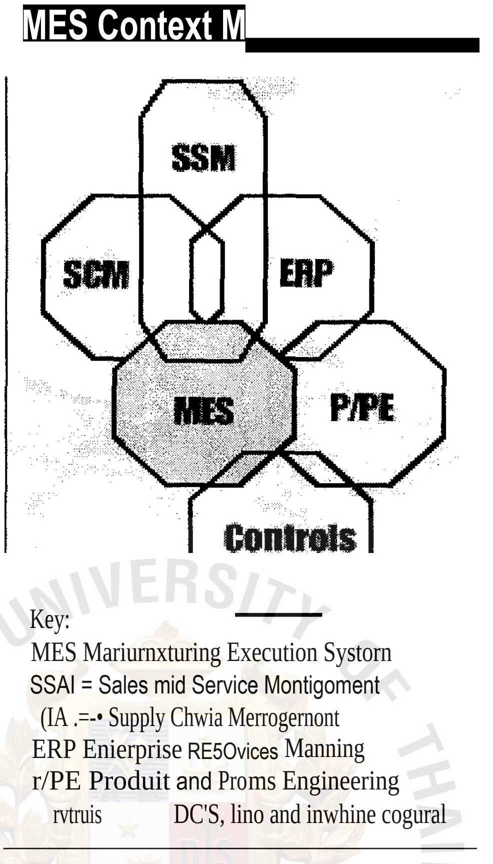



Figure 2.1. MES Context Model (Vinhais 1998).



## 2.3 MES Functional Model

The Manufacturing Execution Systems Association (MESA International) has prepared a list of activities descriptions of the various areas of production or operational management that would be included in a full MES implementation. The MES functional model is shown as Figure 2.2.

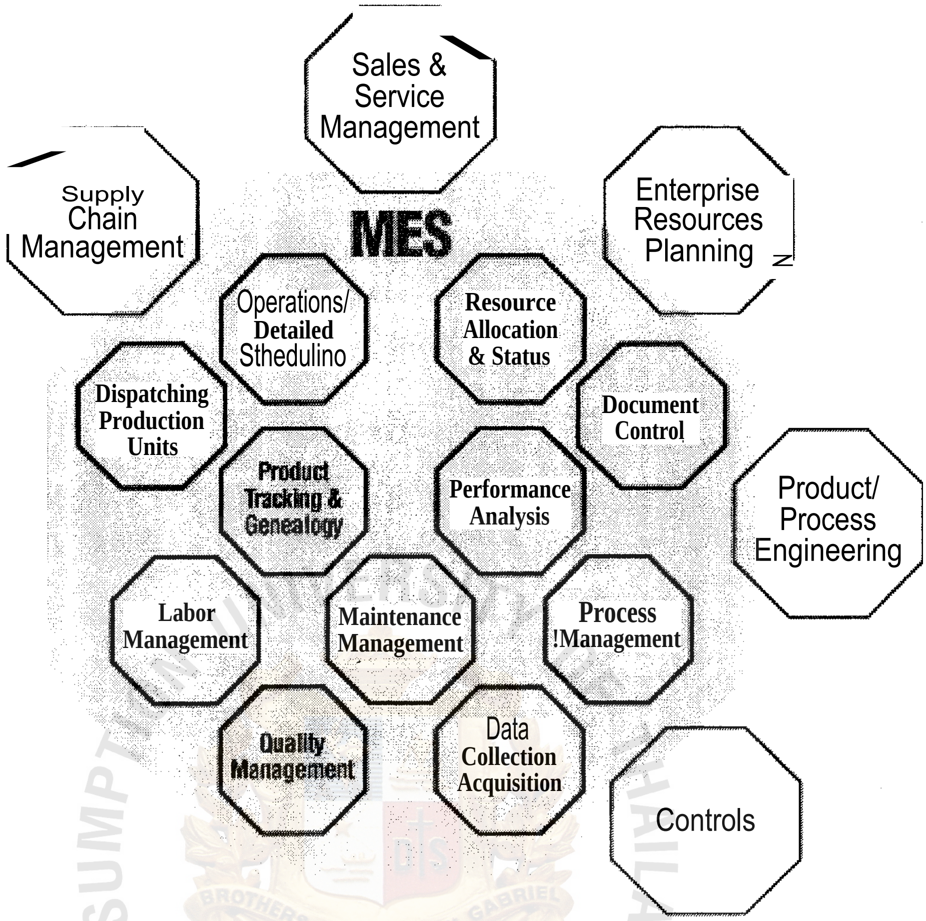



Figure 2.2. MES Functional Model.

They are as follows:

(1) Resource Allocation and Status

To manage resources including machines, tools, labor skills, materials, other equipment, and other entities such as documents that must be available for work to start at the operation. (Fraser 1992)

(2) Operations/Detail Scheduling

Provide sequencing based on priorities, attributes, characteristics, and/or recipes associated with specific production units at an operation.

(3) Dispatching Production Units

Manage flow of production units in the form of jobs, orders, batches, lots, and work orders. Dispatch information is presented in the sequence in which the work needs to be done and changes in real time as events occur on the factory floor. (Fraser 1992)

(4) Document Control

Control records/forms that must be maintained with the production unit, including work instructions, recipes, drawings, standard operation procedures, batch records, engineering change notices as well as the ability to edit "as planned" and "as built" information.

(5) Data Collection/Acquisition

This function provides an interface link to obtain the inter-operational production and parametric data. The data may be collected from the factory floor either manually or automatically.

(6) Quality Management

To provide real time analysis of measurements collected from manufacturing to assure proper product quality control and to identify problems requiring attention. This may include Statistical Quality Control or SQC tracking and management.

(7) Process Management

Monitor production and either automatically corrects or provides decision support to operators for correcting and improving in-process activities. These activities may be inter-operational and focus specifically on machines being monitored and controlled, as well as intra-operational, which is tracking the process from one operation to the next. (Fraser 1992)

(8) Maintenance Management

Track and direct the activities to maintain the equipment and tools to insure their availability for manufacturing. And also insure scheduling for preventive maintenance.

(9) Product Tracking and Genealogy

Provides the visibility to where work is at all times and its disposition. Status information may include who is working on it; components, materials by supplier, lot, serial number, current production conditions, and any alarms, rework, or other exceptions related to the product. The on-line tracking function creates a historical record, as well.

(10) Performance Analysis

This provides real time reporting of actual manufacturing operations results along with the comparison to past history and expected business results. This includes measurements as resource utilization, resource availability, product unit cycle time.

## 2.4 Computer Software Systems Used in Manufacturing Management

Firstly, business management has used computerized systems for a number of years primarily for financial requirement. The orientation toward financial application is one reason most systems relating to manufacturing are not as effective as might be expected. During the past forty years, manufacturing planning systems have evolved through Material Requirements Planning (MRP), Manufacturing Resources Planning (MRPII), and Enterprise Resources Planning (ERP) and have become an important part of company-wide management planning. These systems are frequently called manufacturing control systems or manufacturing planning systems. They will be referred to as planning systems that comprise the "planning layer".

Secondly, there are also complicated computers and programmable logic control (PLC) systems which are used to control devices on the plant floor. These systems comprise "control layer". And the last one which makes up the systems and operating methods in the real world to accomplish production is named "execution layer" which is between the planning layer and the control layer.

Consequently, there are three layers of manufacturing computer systems which are able to apply in production management. (Figure 2.3)

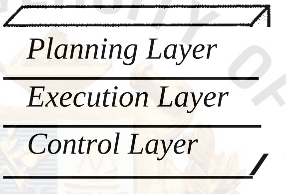



Figure 2.3. Manufacturing Computer System Hierarchy (McClellan 1997).

Planning Layer

Material Requirements Planning (MRP) systems were developed to provide better information to plan inventory quantities and costs. They are based on a master schedule that indicates the quantity of products by specific part numbers to be built in a given time period. Once the master is available, this can be matched against the bills of material for each product to determine the material quantity that will be required. If the current inventory and lead time for each part number are included in the equation, a plan can be developed that shows when to start production and how much capacity is required.

Manufacturing Resources Planning (MRPII) systems are a further development of MRP that broaden the application to include other company departments such as finance, marketing, engineering, even purchasing.

Next, Enterprise Resources Planning (ERP) is the latest evolution and broader than MRPII systems, usually including distribution, product data management and supplier management. ERP systems are built around later information technology, database management system, client/server system and also improved communication capabilities among systems such as CAD, product data libraries, and plant floor data collection devices.

An understanding of the details and modules that make up these systems is helpful in seeing the relationship between planning and execution layers. The modules included in this outline are generalized and are not completely described or representative of any system that any supplier might deliver.

(1) Master Production Schedule (MPS)

This is an anticipated build schedule for end products to be manufactured, how many are needed, and when they are needed.

(2) Material Requirements Planning (MRP)

This module provides formal plans for each part number in the product bill of material. MRP schedules bill of materials when they are needed; no earlier and no later (Russell and Taylor 2000)

(3) Capacity Requirements Planning (CRP)

This is a definition of the existing capacity to manufacture, usually expressed in some term of output. (McClellan 1997)

Another definition is that CRP is a computerized system that projects the load from a given material plan onto the capacity of a system and identifies underloads and overloads. (Russell and Taylor 2000) The objective in capacity planning is to measure capacity against planned production.

(4) Shop Floor Control

This is used to measure when shop orders are in their routing. This information is a very useful tool to compute inventory value and execution of material plans; it can include detailed scheduling of individual jobs.

(5) Inventory Control

Most companies, the amount of materials in inventory are a major factor affecting company cost management. Inventory knowledge is equally important when planning manufacturing to ensure adequate material is available to meet planned production.

(6) Product Data

All data supporting the products resides in this module. The data can include bills of material, routings, standards, process data, quality assurance standards, machine set-up times, part configuration, tool data, etc.

Many manufacturing planning systems currently in place have only these or some of these above. Moreover, most planning computerized systems run in a batch mode, with only function running and accessible at any time.

Generally these systems do not allow manufacturing people to directly access through computer system. Information is most often provided in the form of printouts. Any change must be responded only by the authorized person. Planning systems are usually reactive or reporting system that can indicate a change has been made. They are not designed to be proactive to anticipate any shop floor changes.

Control Layer

At the other end of manufacturing process is the control systems layer; it makes process and machine functions occur. The control layer concerns inputs and outputs, or status points of the process. These points can be relayed as they occur, tended as part of the functionality within the controls themselves, or stored in database for analysis.

Some examples of device control systems include:

(1) A system used to control the movement of one or more robotic devices.

(2) A quality assurance test station with ability to retrieve specific product test requirements, monitor and collect test information, and store and/or distribute the results.

(3) A CNC (Computerized Numeric Controller) machine controller that converts a CAD program to the actual production of a part through motor control and measurement.

(4) The process controllers that monitor and control flow rates, pressure, etc.

The above device systems used for equipment control can be very sophisticated, most using programmable logic controller (PLC) or computer. Although some companies have the technical resources to build their own control systems, most often these systems are supplied by the process or device vendor with necessary logic to accomplish the necessary functions.

Execution Layer

In practicality, there is a big question in communicating between or with their control systems. There have been many products on the market that were meant to address this communication question. The most widely promoted was the Manufacturing Automation Protocol (MAP). MAP has become a common method of connection between computers and plant floor devices or equipments from different suppliers. However, this did not solve two major problems, which are what and when to pass the information.

Next, the execution system, which is the layer between the planning system and the device control system, has come up. The execution system communicates with planning and control layers, translating data from both sources, interpreting that data. The easiest job of the MES is to process a question and deliver a specific answer. More sophisticated system can process a series of questions and present or implement the answer automatically.

## 2.5 MES Core Functions

The manufacturing planning layer and the control layer descriptions show there is very little relationship between them. The MES fits among these two layers and it is able to communicate with the planning system and the device control system through an on-line system.

The MES layer can be divided into 2 functionalities; the first is core functional parts that deal primarily with the actual management of work orders and the manufacturing resources. The second is support functions, which include peripheral or supporting activities.

Although not every MES product is divided in exactly the same way, these functions are a part of nearly every production system in one form or another. They are considered as core functions because they are interrelated and basic to most production systems.

Michael McClellan (1997) also defined seven common categories of the MES core functions are as follows:

2.5.1 Planning System Interface

To define what information is to be transferred and what format and timing should be in place, collaboration with and between the MES vendor and the planning system vendor is recommended. This interface is usually custom-developed software that fits the specific planning system and the MES.

2.5.2 Work Order Management

The MES accepts either automatically or manually entered information that identifies what is to be produced and its quantity. This module manages changes to orders, establishes and maintains schedule, and maintains prioritized plan.

2.5.3 Workstation Management

This function is responsible for implementing the direction of the work order plan and the logical configuration of the workstations. Operation code assignment, work orders optimization, program download and retrieval; all of these are example responsibilities within this segment.

2.5.4 Inventory Tracking and Management

This segment develops, maintains and stores the details of each lot of inventory including the current status. The particular job on this segment is to manage all raw materials and work-in-process inventory, locate and retrieve all supporting information.

2.5.5 Material Movement Management

This function must simply determine when to move what from where to where and issue the appropriate instruction. The instruction can be for manual movement or automatically complicated system.

2.5.6 Data Collection

This function is the "eyes and ears" of the MES, allowing the system to remain current. This is the primary method for all personnel to communicate with the MES. The application can be as simple as bar code scanning or machine monitoring. (McClellan 1997)

2.5.7 Exception Management

This is the custom function of MES to response to unanticipated events that affect the production plan. For example, how do production people respond when machine breaks down or material does not arrive on time? (McClellan 1997)

All above functions shall be integrated to be a system which is an example of how MES can be effectively applied to reduce work-in-process and improve customer response time as shown in Figure 2.4.

The system maintains a model of what has been finished, what is being finished, and what is to be finished. It uses current information regarding status of each lot or unit in production and determines movement to be made into and out of each workstation.

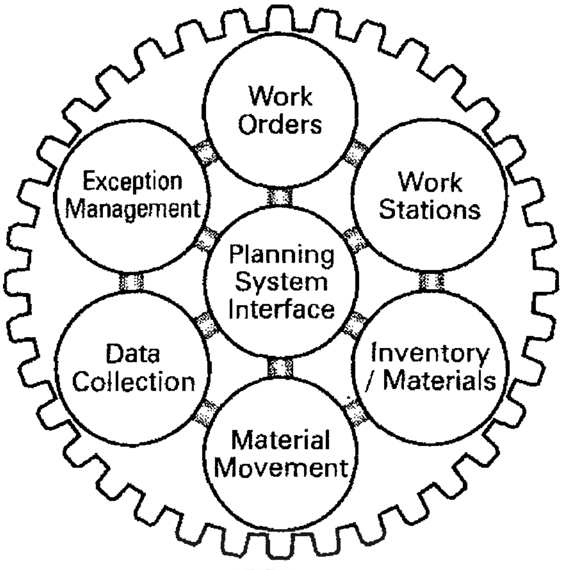



Figure 2.4. An Integrated System of MES Core Functions.

## 2.6 MES Support Functions

This describes other functions that are no less important, but they seem one dimension removed from production. These supporting functions are the most common and shown to give an indication of the MES application. MES is a continuously evolving part of manufacturing systems, and even if some company does not need some function today.

Michael McClellan (1997) divided into eight categories of the MES support functions included are:

### 2.6.1 Maintenance Management

This module provides historical, current and planned maintenance events. and this also can be a significant aid to production.

2.6.2 Time and Attendance

This can be as simple as a data from a time clock or as complicated as a badge scanning system. The MES can use this information to send to another system such as payroll, costing administration.

2.6.3 Statistical Process Control

This function focuses on continuous process monitoring rather than the inspection of finished product.

2.6.4 Quality Assurance

This application includes following features; receiving inspection, non-conformances, corrective action, etc.

2.6.5 Process Data

Collect and manage the process information. This function can be a standard package developed for particular application.

2.6.6 Documentation Management

This function is a general extension of techniques and it is excellent tool that provide immediate with accurate information wherever needed.

2.6.7 Genealogy/Product Traceability

This is frequently used for warranty and product statistical information, as well as inventory use information. Moreover, this is a basic built-in function of many MES applications.

2.6.8 Supplier Management

This function is responsible for synchronization all of outsourcings with manufacturing.

All of MES core functions and support functions are integrated via on-line computerized system including accumulation of tools in order to accomplish production. Each function is a part of MES and associate with others. (Figure 2.5) In addition, the accessibility of all information available in these functions will significantly enhance the ability of respond to and control manufacturing issues.

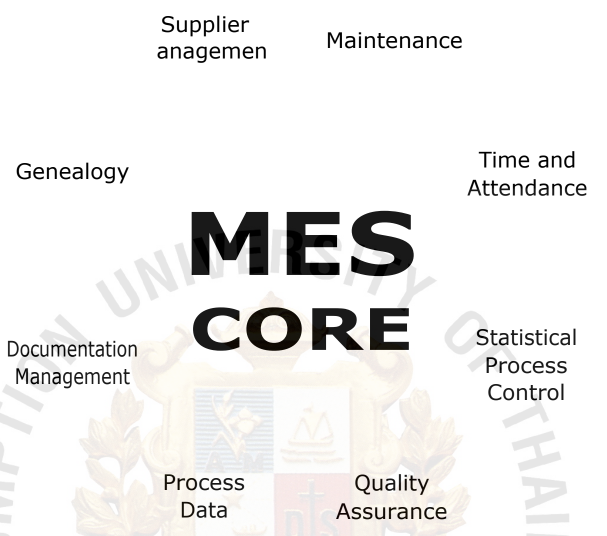



Figure 2.5. MES Concept; Core Functions and Support Functions.

## 2.7 System Configuration and Architecture

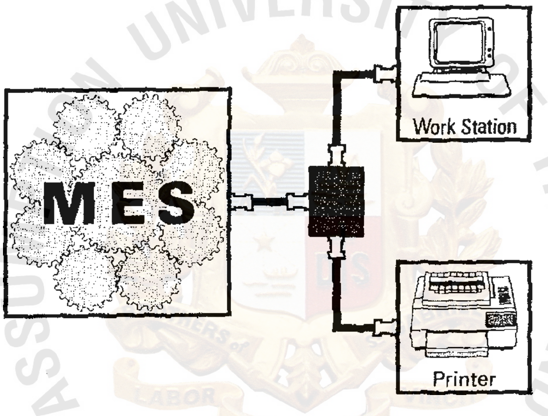
The system architecture is likely to be different for each manufacturing execution system application. Systems can range from one personal computer with a display screen to a hierarchy of computers on worldwide network.

Most computer applications fall into two categories: decision support system (DSS) and on-line transaction processing (OLTP). OLTP system is used in many area of business, particularly where an immediate response time is necessary. Their reliability and availability must be very high including information accuracy & consistency. DSS system is used to analyze data and create reports. This is generally not time critical.

Therefore MES definitely falls into OLTP category and must provide real time on-line information. However, in most cases, the MES configuration will not be static. There will be application changes and system equipment changes. (Harkey and Edwards 1994)

The Essential Client/Server Survival Guide (1994) summarized and provided five illustrations of possible system configuration are as follows;

(1) Manual data entry through the terminal




**ASSEMBLY**

Figure 2.6. Manual Data Entry through the Terminal.

(2) Planning system, robot systems are applied and linked to MES

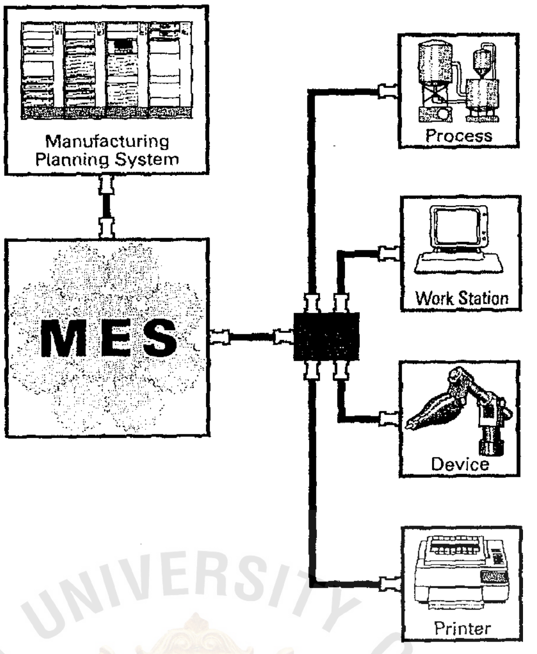



Figure 2.7. Planning System and Device Linked Together with MES.

(3) CAD/CAM and data management are included to enlarge the whole system

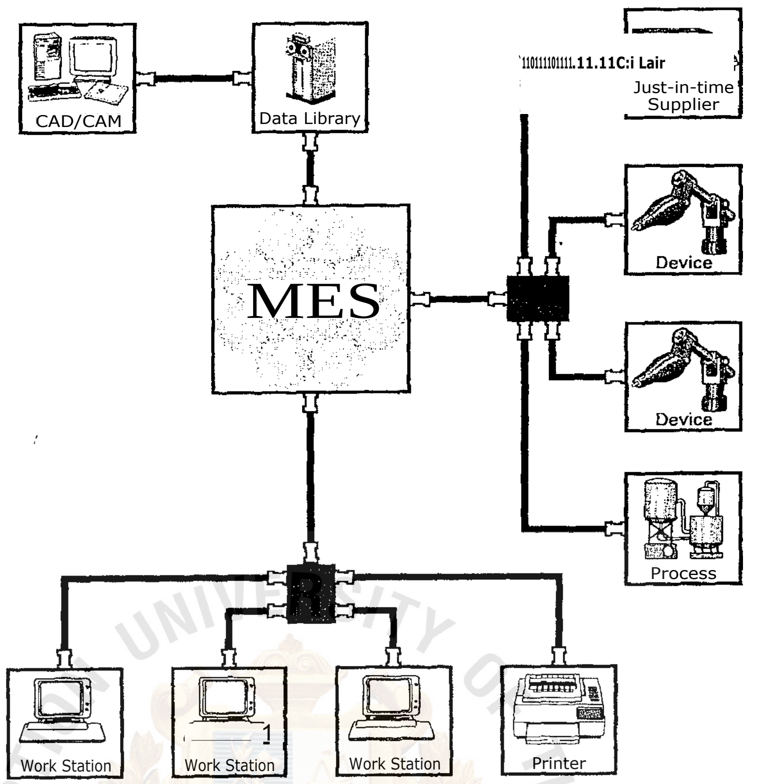



Figure 2.8. Device, CAD/CAM and Data Management Linked with MES.

(4) Multiple departments or factories

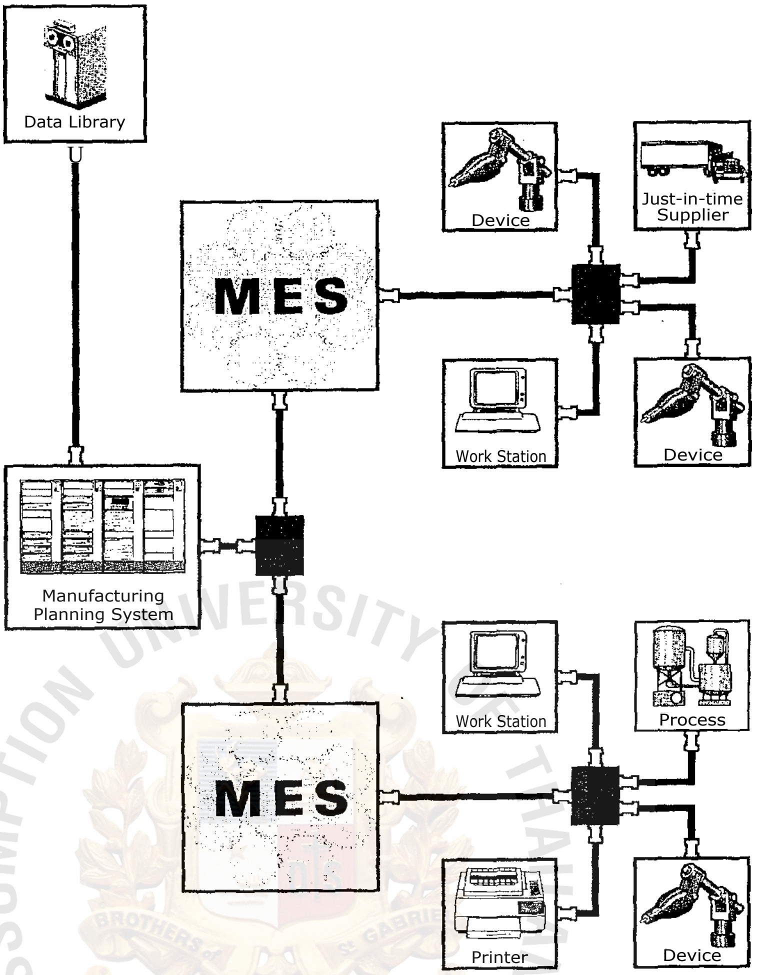



Figure 2.9. Multiple Departments or Factories.

(5) Hierarchical arrangement of MES applications

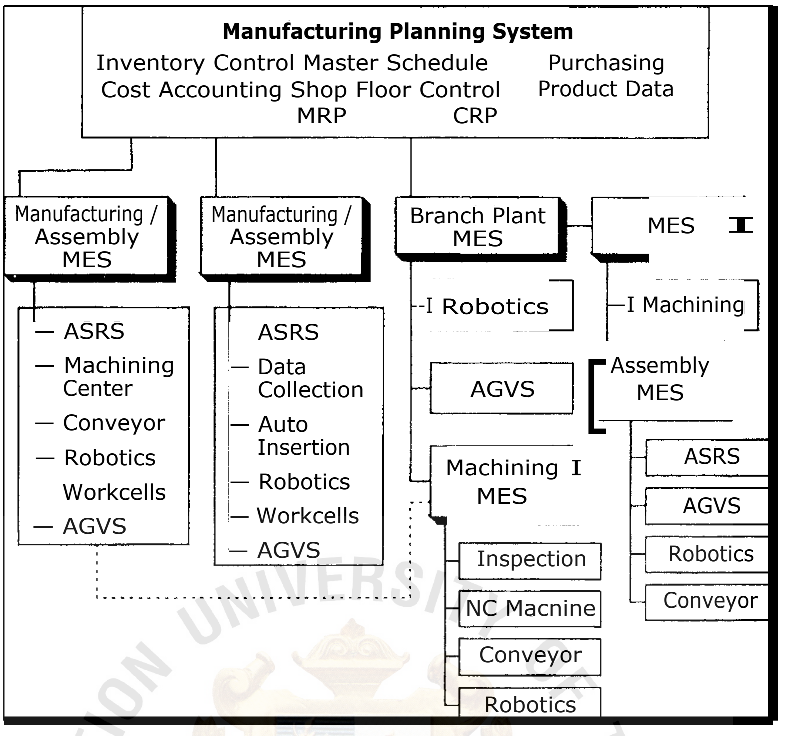



Figure 2.10. Hierarchical Arrangement of MES Applications.

## 2.8 Advantages and Disadvantages of MES

MES provides a lot of benefits as suggested by the MESA International (1994); they have conducted a study of user companies and offered the following list of benefits from using a computer-driven MES:

(a) MES reduces manufacturing cycle time.

(b) The system helps to reduce or eliminate data entry time.

(c) Reduces work-in-process.

(d) There could improve the planning system.

(e) The system minimizes or eliminates paperwork.

(f) Improves product quality.

Moreover, another advantage is that an MES can be proactive; causing events to occur or tasks to be implementing according to the factory's operating methods without human intervention.

Joseph A. Vinhais (1998) also suggested that the MES has benefits in many aspects especially on quality control segment. The benefits are discussed below:

(1) Improves CADs and CAMs

An MES system eliminates the errors came from drawing changes, distributed copies but not reflect to the latest drawing revision. The system will be automatically update engineering change notices wherever they appear in the manufacturing environment.

(2) The system ensures that the correct revisions of controlled document are the only ones available.

(3) Helps to monitor in real time whether there are any shop-floor bottlenecks occurred and make appropriate changes.

(4) MES easily shows gages distributed throughout the facility that are due for calibration.

(5) Tracks the quality costs associated with inspection, auditing and data collection. Using Pareto charts, department managers can easily compare predicted costs vs. actual costs.

(6) The MES system with SPC on-line tracks production time and quantities. This can electronically flag operators when a process is due for inspection.

(7) The system can send an alarm throughout the network about a problem on the shop floor.

## 2.9 The Future for MES

MES is evolving to make systems easier for design, development, installation and operating. The following are just a few of newer terms today:

(1) Object-oriented technology

(2) OLE

(3) Plug and play.

(4) Application Programming Interface (API)

Soon the computer system will be possible to combine together different applications on different machines with different operating system. Moreover, user might easily interface between a software system application and the outside application via Application Programming Interface (API). And now there are a number of technologies which are offering and making the idea of "plug and play" become a reality.

## 2.10 Economic Analysis Methodology

In the method of economic analysis, there are many approaches to be used as follows:

(a) Breakeven Analysis

(b) Present-Worth Evaluation

Breakeven Analysis

In analyzing the proposed system, only time measurement is not enough for decision making since the new system needs the investment. Breakeven Analysis can determine whether the alternative is equally acceptable. This method is quantitative analysis using relations of revenue and cost of project.

Present-Worth Evaluation

This method is to determine how much money is worthwhile to invest in order to receive a given return in some years' time. The answer obviously depends upon the interest rate used in the evaluation.

Further, to perform the economic analysis, estimates may be needed on financing interest rates, life of assets, revenues, costs, tax, etc.

The present-worth (PW) method of alternative evaluation is very popular because the future expenditures or receipts are transformed into equivalent value now. That is, all the future amounts of money are converted into present value.

Thus, whether alternatives involve disbursements only (service), or receipts and disbursements (revenue), the following guidelines are applied to select an alternative using the present worth measure of worth: (Blank and Tarquin 2002)

For one alternative, if PW > 0, the requested rate of return is met or exceeded and the alternative is financially viable.

For two or more alternatives, when only one can be selected (i.e., alternative are mutually exclusive). Select the alternative with PW value that is numerically largest, that is, less negative or more positive, indicating a lower PW of cost cash flows or larger PW of net cash flows of receipts minus disbursements.

The alternative must be compared over the same number of years. We use the symbols as:

PW = sum of money at a time denoted as the present.

F = value or sum of money at future time.

A = a series of consecutive, equal, end of period amount of money.

n = number of interest rate, years, etc.

= interest rate per interest period.

Thus, the following expression will allow determination of the present worth P of a given future amount F after n years at interest rate i.

$$P = F[1/(1+i)^n]$$

Or another form: $P = F(P/F, i\%, n)$

Another equation will give the present worth P of an equivalent uniform annual series A which begins at the end of year 1 and extends for n years at an interest rate i.

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

Or another form: $P = A(P/A, i\%, n)$

# III. THE EXISTING SYSTEM

## 3.1 Company Profile

The Microchip Technology is an international company, were found in 1993 by Mr. Steve Sanghi, headquartered in Chandler, Arizona with design facilities in Mountain View, California and Bangalore, India; semiconductor fabrication facilities in Tempe and Chandler, Arizona and Puyallup, Washington; and Integrated Circuit (IC) assembly packaging and test operations near Bangkok, Thailand. The company has focused its technology, engineering, manufacturing and marketing resources on synergistic product lines:

(1) PlCmicro® microcontroller (MCU).

(2) A dsPIC™ family of Digital Signal Controller.

(3) KEELOQ® security devices.

(4) An extensive portfolio of analog/interface products.

(5) MicrolD® RFID tags.

(6) High-endurance Serial EEPROMs

The Company's design and technology advancement facilities are located in Chandler, Arizona; Mountain View, California; Austin, Texas; New York; Lausanne, Switzerland; and Bangalore, India.

On the Chandler and Tempe, Arizona campuses, as well as an additional 100,000 square feet of manufacturing space on the Puyallup, Washington campus, Microchip's state-of-the-art wafer manufacturing facilities result in wafer production yields that are among the best in the industry.

The facilities in Thailand serve as the foundation of Microchip's extensive assembly and test capability.

In conclusion, Microchip has a fully integrated manufacturing beginning from wafer fabrication to testing so they can conduct and operate all of these functions such as Research and development, design, mask making and a majority of assembly packaging and quality assurance testing at facilities wholly-owned. Hence, the company can be consistent quality through total control in all phases of production. Moreover, the company also approaches manufacturing along with rigorous use of advanced Statistical Process Control (SPC) and a continuous improvement culture.

Microchip supports its global customer base from direct sales and engineering offices in Asia, North America, Europe and Japan. Offices are staffed to meet the high quality expectations of our customers, and can be accessed for technical and business support.

## 3.2 Conceptual Overview

This section will give a high-level description of material flow through the Microchip Technology, Thailand (MTAI) and Subcontractors (SUBCONs) operations.

Generally, the wafers will be received from wafer fabrication (FAB) factories in the original wafer lot number. Several wafer lots will be shipped together on the same invoice. Then, the wafer lot information which consists of number of good die, total quantity, etc.; will be transferred whole information to MTAI and saved into the BA-WIP system. The physical wafers will also be stored in the MTAI wafer/die bank.

The wafer lot may be shipped to any SUBCON for assembly packaging or assembled in-house at MTAI. In case of MTAI assembly, wafer lot will undergo an Incoming Quality Assurance (IQA) inspection prior to release and issue the wafer to production. As lots move through the assembly operation, the workers have to manually record and track the lot information.

In terms of MTAI assembly, this can be viewed as two major manufacturing processes; front-end assembly (which includes mount & saw, die attach, and wire bonding operation), back-end assembly (which includes mold, laser mark, solder plate, and trim & form/singulated operation).

Apart from MTAI assembly, SUBCON assembly is alternative operation and this could be determined by current load balancing and/or packaging capability at MTAI. The SUBCONs will completely perform materials, product tracking without details by individual process. Then, the assembled products are typically transferred back to MTAI for final test. Furthermore, SUBCONs wafer/die bank may return the wafer back to MTAI after their allocation finished.

For test operation, there are many kinds of products which require different test flows; however, the test flow is generally made up of a sequence of test, bake and QC sampling test steps, followed by a scan step, and then Final Outgoing Inspection (FOI). The difference in test flows (from a sequence standpoint) is the number and sequence of test and QC sampling test steps.

Both assembly packaging and test process flows mentioned above are illustrated in Appendix A, B.

Figure 3.1 is shows the consideration of product flow throughout Microchip Thailand. For in-house assembly, the average cycle time is three days approximately, with two days for assembly plus one day for test. Whereas SUBCONs usually spend five days to accomplish assembly and take additional one day for test at MTAI site so totally SUBCONs assembly cycle time is six days including the final test.

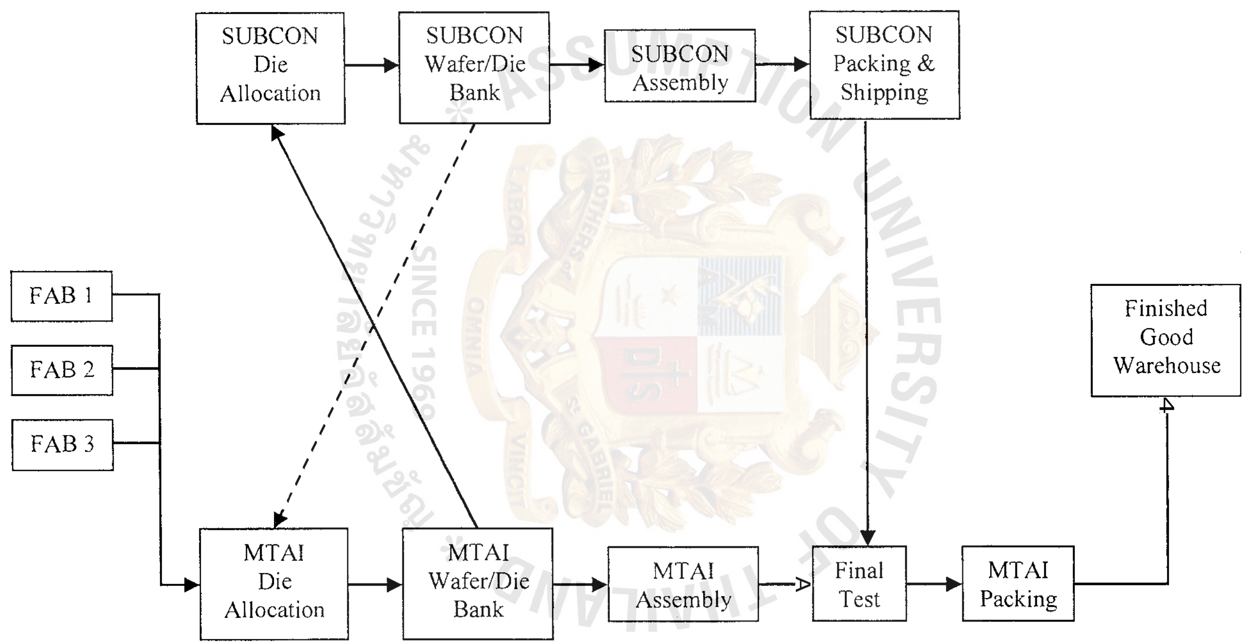



Figure 3.1. Product Flow throughout Microchip Technology, Thailand (MTAI).

### 3.3 Manufacturing Procedure via the Existing System

There are many steps to manufacture the Integrated Circuit (IC.) which are applicable for Microchip Technology, Thailand (MTAI) as follows:

(1) MTAI Wafer/Die Bank receives wafers including theirs information through the BA-WIP transaction system.

(2) Aggregate production planning issue assembly request document and load followed Master Production Schedule (MPS) which is created by BA-WIP system.

(3) MTAI Wafer/Die Bank issue IQA the Assembly Instruction (AI) document to tell which wafer lot need to do inspection.

(4) IQA perform inspection and verification whether the wafer information in paper such as quantity, wafer ID, FAB site, etc. are correct and compliant with physical wafers.

(5) IQA release wafer through production floor if there is no nonconformance.

(6) Production starts process of mount & saw operation.

(7) Put the wafer into automatic dicing saw machine to make a small piece as dimensional drawing diagram required. This drawing is created by Product Data Characteristic (PDC) database system.

(8) Record lot quantity, part number of saw blade used, input & output quantity, mount & saw machine number with parameter, number of defects, etc. into paper log sheet.

(9) Then move to die attach operation, this process needs to attach die on the leadframe via adhesive epoxy material or die bond material.

(10) Record epoxy type, leadframe part number & supplier, input & output quantity, die attacher machine number & parameter, number of defects, etc. into paper log sheet.

(11) Put the die attached parts into oven for curing.

(12) Record curing machine number, program profile name, etc. into paper log sheet.

(13) Bond with 99.99% purity of gold wire.

(14) Visual inspection after bonding and record number of defects, what defects criteria are, part number of bonding tool, input & output quantity, etc. into paper log sheet.

(15) After wire bonding finishes, the parts must be moulded with molding plastic compound

(16) Record molding compound type & part number, input & output quantity, mold machine information, number of defects, etc. into paper log sheet.

(17) Put the molded parts into oven for curing.

(18) Record post mold curing machine number, time-in, time-out, etc. into paper log sheet.

(19) Laser mark the information on the top & bottom surface of the plastic package. This information would include manufacturer, country of origin, and device code.

(20) Record input & output quantity, laser mark machine number, number of defects, etc. into paper log sheet.

(21) Send to solder plate at SUBCON. The lot information has to be shipped together with the shipment.

(22) SUBCON sends back MTAI the data of input & output quantity, and number of defects via MTAI lot traveler.

(23) Trim and form the parts and also do singulation. (before this process, the parts are in strip form)

(24) Record trim and form tools, input & output quantity, machine number, number of defects, etc. into paper log sheet.

(25) Send to final test

(26) Put the assembled part to test station.

(27) Select test program and appropriate equipments which consist of tester, handler and load board. For testing (production task)

(28) Record test program name, lot quantity, equipment information, defects, etc. into paper log sheet.

(29) Bake the tested parts in the oven. This is an option depending on device.

(30) Submit to QC sampling test. QC person chooses test program, and appropriate equipments

(31) Record test program name, lot quantity, equipment information, defects, etc. into paper log sheet.

(32) Visual scan lots by pattern recognition system whether there are physical defects including wrong markings on top surface.

(33) Record lot quantity, equipment information, defects, etc. into paper log sheet.

(34) Pack the parts with packing material. And put label (which consists of device name, quantity, product type) for identification.

(35) Submit to QC FOI for finalize inspection. And record the result.

(36) Send to finished good warehouse and will be ready to ship to customer.

Above are complicated steps and procedures of MTAI in-house manufacturing that production and QC people must follow. All steps are either paper work or manual working process especially data record such as machine information, lot number, device name, quantity, number of defects, etc. thus there is no connection with particular process database. They are separated to working shift to working shift or man to man in their operations. Hence, they must key and arrange data in computer again that is a reason behind why each process spends a lot of time and no information accuracy. The total cycle time takes two days for assembly plus one day for test.

The existing procedure of MTAI manufacturing system is summarized as shown in Figure 3.2.

Therefore, The existing system consists of manufacturing processes run on many systems, many platforms such as BA-WIP system used for MTAI internal product tracking, PDC database used for collecting information of product characteristics and SPC system used for identifying quality problems and their causes through c-chart, Pareto diagram at QC monitoring processes.

Moreover, Microchip Worldwide offices found difficulty of product traceability and tracking including there is less accuracy due to manual data recording, human error.

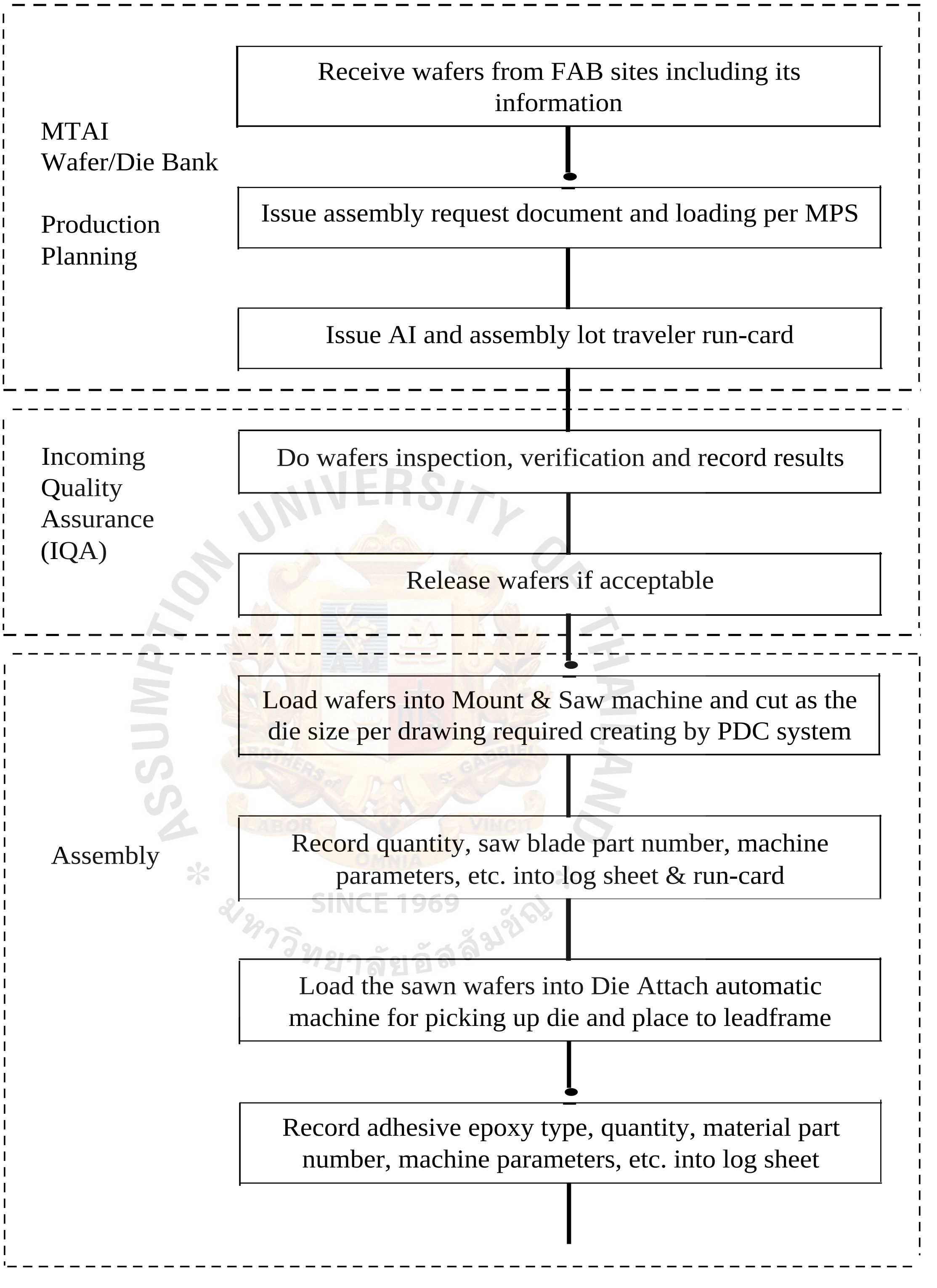



Figure 3.2. MTAI Manufacturing Procedure.

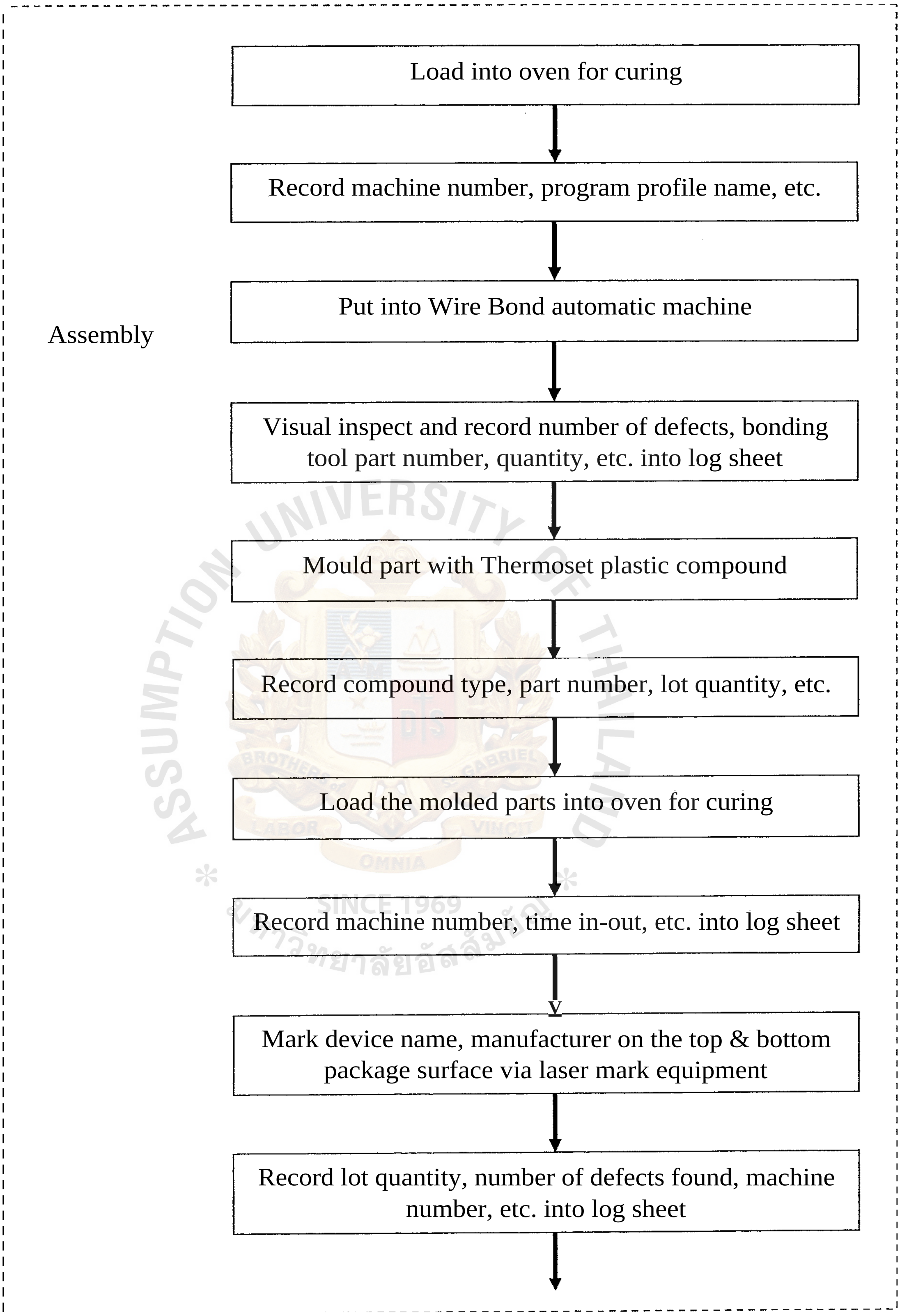



Figure 3.2. MTAI Manufacturing Procedure. (Continued)

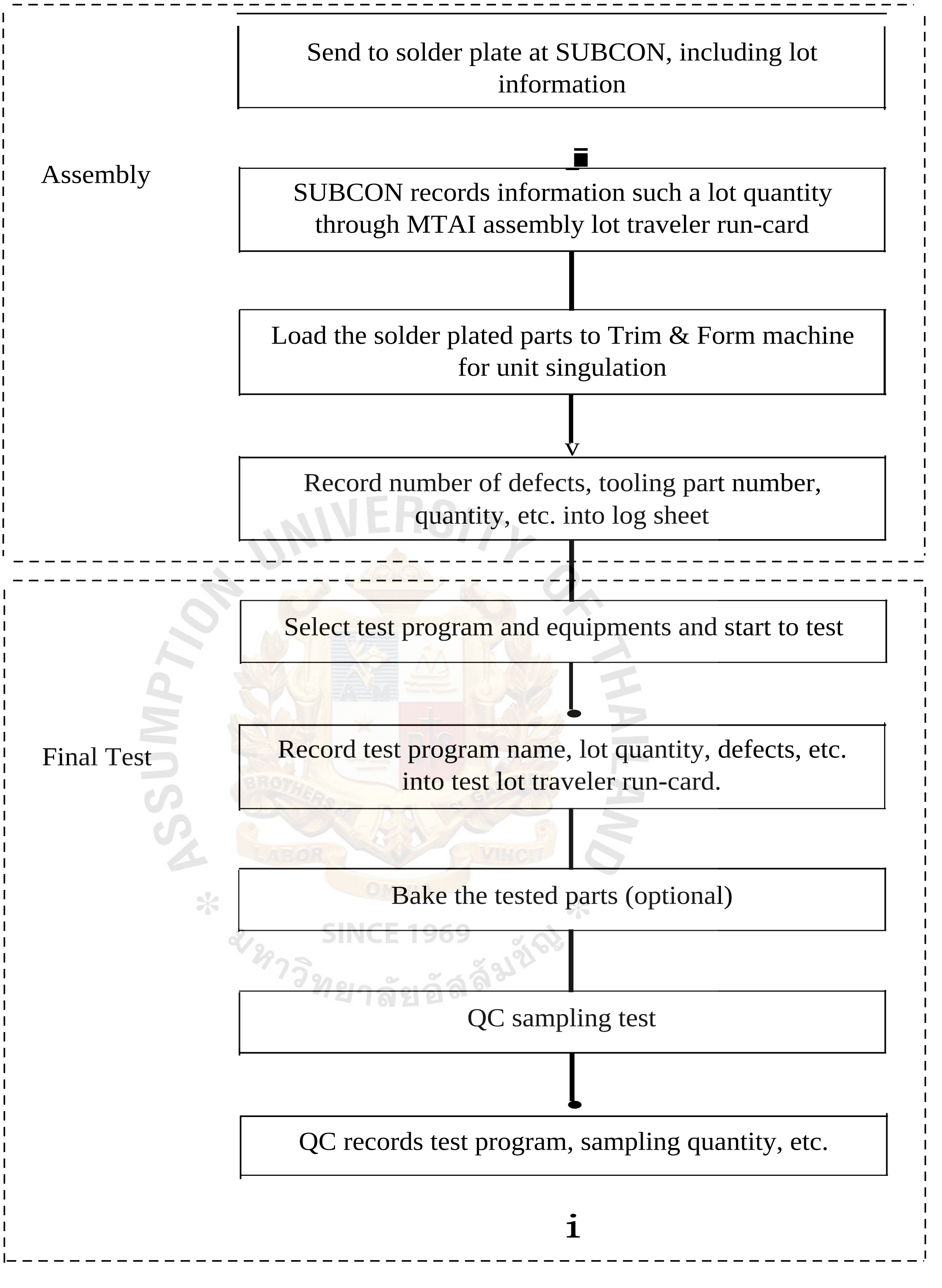



Figure 3.2. MTAI Manufacturing Procedure. (Continued)

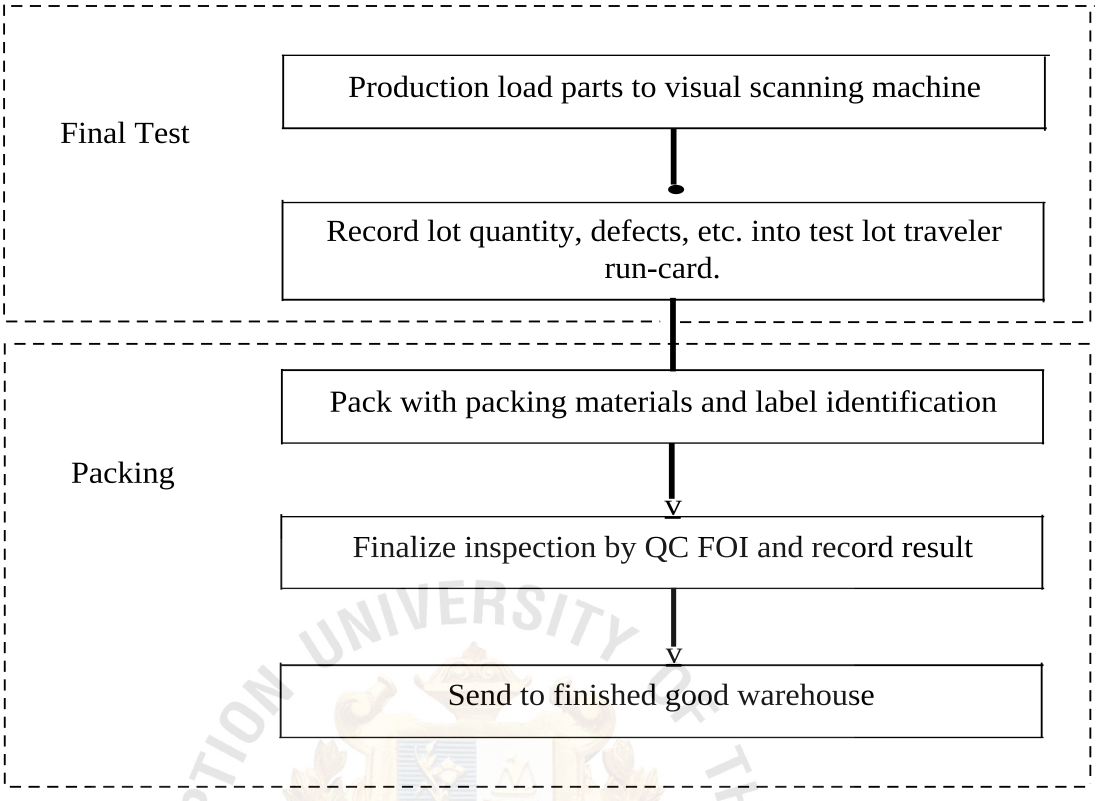



Figure 3.2. MTAI Manufacturing Procedure. (Continued)

## 3.4 Problem Definition

According to the mentioned existing flow chart and manufacturing procedure, there are many faults that generate problems for each manufacturing process as follows:

(1) A lot of manual works or paper works in particular process i.e. record quantity, record machine information, etc. on both production and QC groups.

(2) Time spent is too much for recording the data into log sheets.

(3) There is no information accuracy or the inventory may be double counted or be missing due to human errors.

(4) There is a risk to use wrong materials, wrong equipments or wrong programs for mass production build.

(5) Difficulty of data tracking i.e. which material batch is used, what machine number is used, which test program is used, which wafer is used, etc.

(6) There are different systems to support manufacturing function such as BA-WIP, PDC database and SPC systems.

3.5 Users' Requirement Specifications

The production people as users are investigated and interviewed partly to analyze flaws of the current system. The MES is set to provide the up-to-date information. The report can be generated at any time as much as needed. The system approaches to automatic paperless system that will minimize or eliminate the time consumption of data records and the non value-added tasks. Not only it will save time but the system will also reduce errors both intentionally and non-intentionally.

In developing system, the data can always be updated through data entry screen by authorized person and be transmitted to linked hardware or other terminal. It also reduces paper work of production and QC groups. However, the users' requirement specifications which they want to help in working documents including the administrative system as follows:

(1) Reduce the paper works and time consuming.

(2) Data accuracy to generate reports and specify what material shall be used for particular lot.

(3) The system must be easy for product traceability and tracking

(4) The system provides a more user-friendly method to access and manipulate data.

(5) Provide on-line or network in operational processing application and require LAN and WAN infrastructure supported.

(6) Standardize the system which includes the function of BA-WIP, PDC and SPC systems.

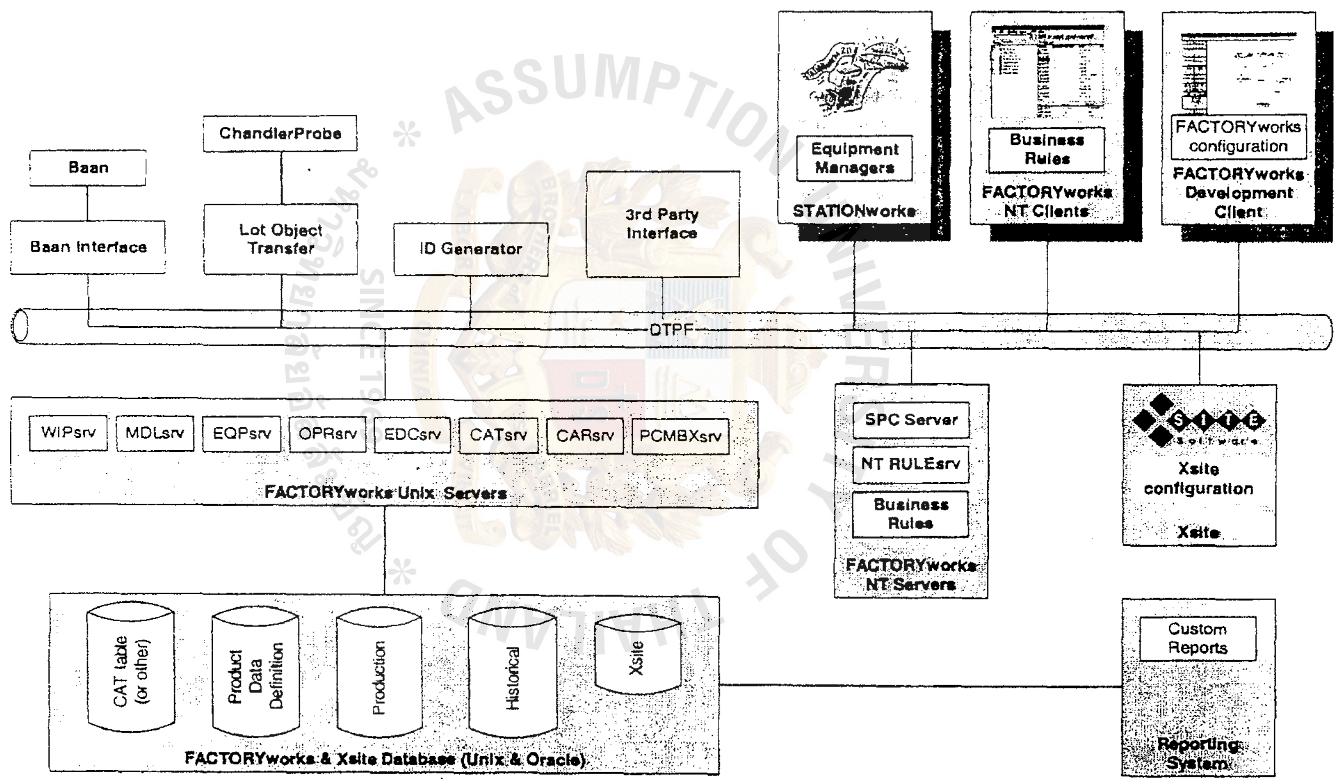
(7) Need flexibility in generating any kind of reports using different data resources.

# IV. THE PROPOSED SYSTEM

## 4.1 System Configuration

In the system design phase, the customization is needed in order to make the most suitable and appropriate system. The proposed system is designed to minimize paper work in process and it also helps to reduce errors in manufacturing process during data entry and transaction. The problem in existing system such as manual work for data recording; verifying lot information; using wrong material/tooling or program; inventory may be double counted or missing. All of these mentioned problems would not happen in the proposed system. The automation software, called as FACTORYworks of the proposed system is specifically designed by Brooks Automation Company; hence, this is more expensive than general software package or licensed software in the market. However, the specification of system is generated to meet MTAI manufacturing's requirements and make their satisfaction because they are main users to do transaction thoroughly network for information distribution.

Following is a schematic of Microchip Thailand FACTORYworks configuration, and what they will be interfacing with the Microchip system environment. (Figure 4.1)




Overall Solution Component Configuration.

There are FACTORYworks servers operated as the MES system to store factory executing production data to Oracle (production database). Multiple instances of the server process (i.e.: WIPsrv, EQPsrv, etc.) run in Unix environment. Whereas the standard system used for user interface is NT Client/Server architecture.

Below are functionalities of each component:

(1) Production Database is the active database used for storing production transaction.

(2) Historical Database (HDB) is used for the report system.

(3) Product Data Definition (PDD) provides product relationship data.

(4) Custom CAT Table database provides miscellaneous data storage.

(5) Xsite is an equipment maintenance application.

(6) NT Rule Server supports all required business rules to operate production system. It can be used for automatic and manual mode.

(7) SPC Server executes SPC specific business rules.

(8) The Baan interface is a bi-directional interface to Baan system for inputting orders, outputting finished products and a conduit for WIP reports from FACTORYworks to Baan.

(9) The Lot Object Transfer is an interface to transfer completed lot data from Chandler Probe or any FAB to FACTORYworks.

(10) The ID Generator is a custom application that creates unique lot ID and Trace Code (Trace Code is a code that Microchip uses for material identification when a lot has been assembled and tested, and almost products are physically marked on the top of assembled package)

(11) STATIONworks will be used for future equipment interfacing.

## 4.2 Hardware & Software Components

To support mentioned system configuration and users' requirements, the proposed system needs to attain the following components:

Database and Application Server N4000 series.

LAN and WAN.

Personal Computers with monitor display for each manufacturing machine.

Bar Code Label Scanners.

Printers for bar code label printing.

FACTORYworks, Xsite

Microsoft Window NT Client & Server.

Application softwares (i.e.; Microsoft Access, Visual Basic 6.0, Power Builder)

(9) Disk Array is used for data storage.

The Figure 4.2 shows the configuration of hardware to run the MES system.

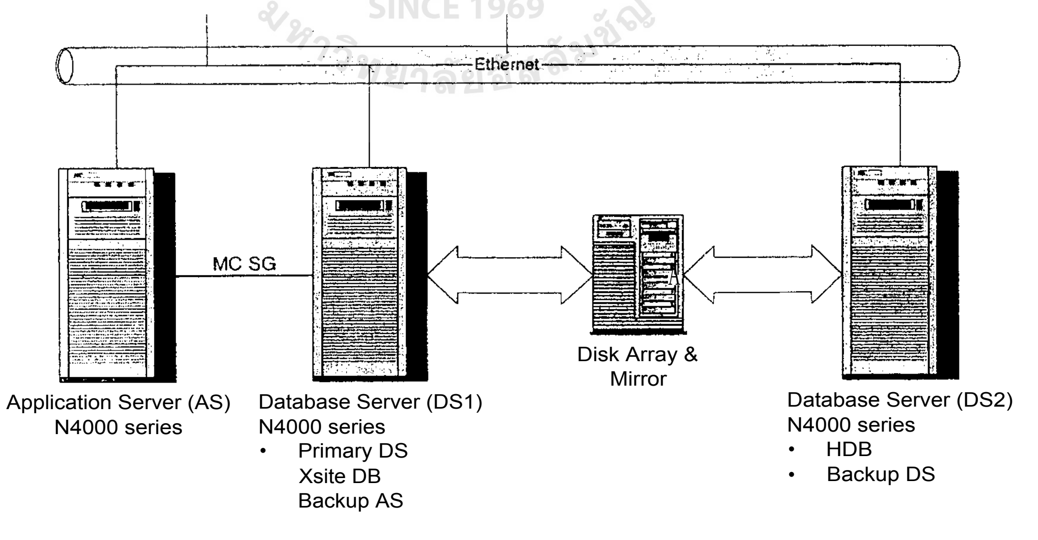



Figure 4.2. Hardware Configuration.

## 4.2 Manufacturing Procedure via the MES

The system describes briefly what the manufacturing tasks transmit as information to computer systems via bar code label scanner; so the system requires no checking during data entry by production workers.

Figure 4.3 illustrates the use of a bar code menu to communicate directly with MES from terminal users or clients, how the system collects data need and whatever production people want MES to do through bar codes. Moreover, the employee ID card also has its badge bar code.



**Sample Data Collection Menu**

When you w sh to start working on a job, scan:

01 1111 | 11 |
START | SHOP ORDER NUMBER | END

When you have completed the job, and it should go to the next regular "*A*' operation, scan:

ACCEPT | SHOP ORDER NUMBER | END

When you have completed the job, and it should go to the Rework ("M") operation following directly after the current operation scan:

111111 it

REJECT | SHOP ORDER NUMBER | END

To send a Job back into the system without working on t, scan:

111111

RESUBM T | SHOP ORDER NUMBER | END

If you lose track of what you've scanned and wish to start over, scan:

Figure 4.3. Sample Data Collection Menu.

The manufacturing procedure of the proposed system will not spend times for data recording into log sheet because the system uses the bar code application to run on whole processes and this application will transmit the information such as material lot information, material type, when lot start or end of each process, etc. Hence, Microchip Thailand needs to request all material suppliers to label the bar code on their product package. Fortunately, all suppliers can support MTAI requirement. The process is shown in Figure 4.4.

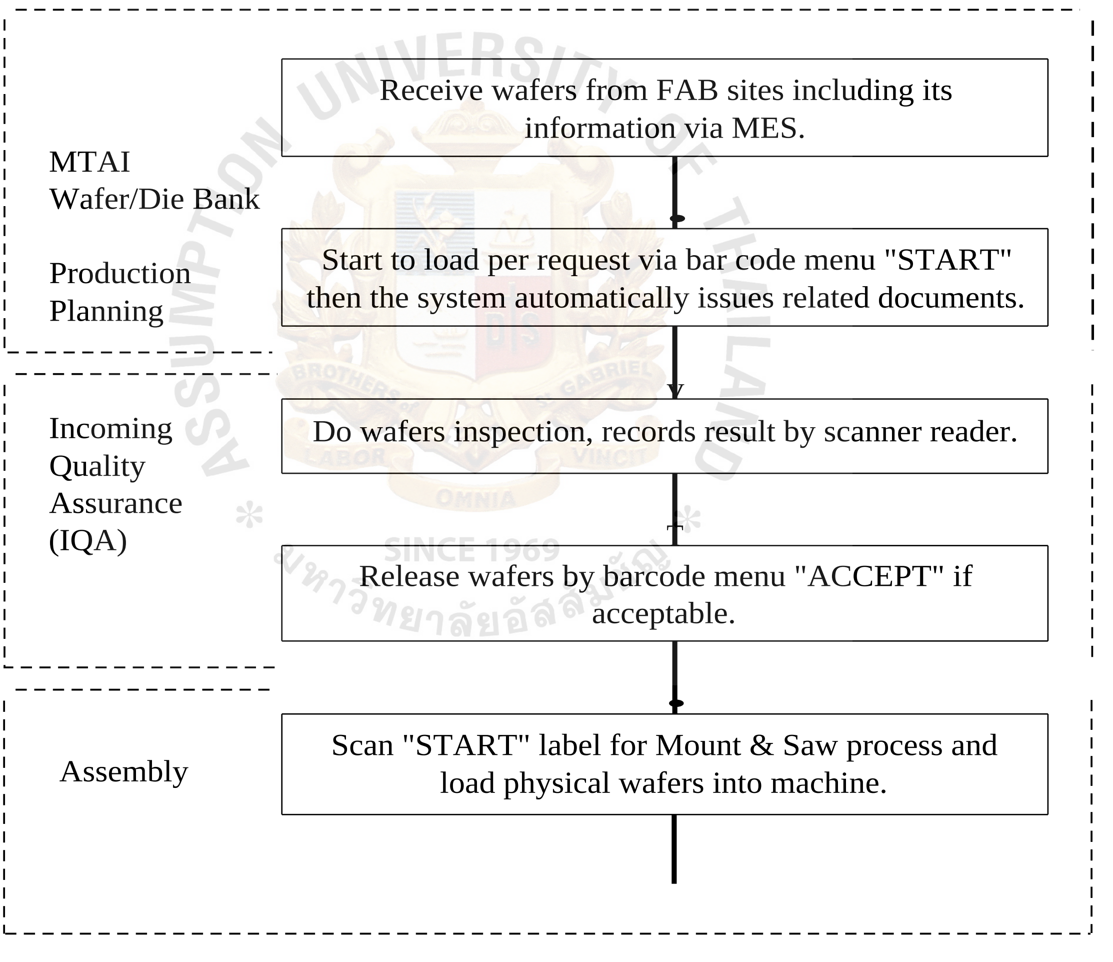



Figure 4.4. MTAI Manufacturing Procedure via the Proposed System.

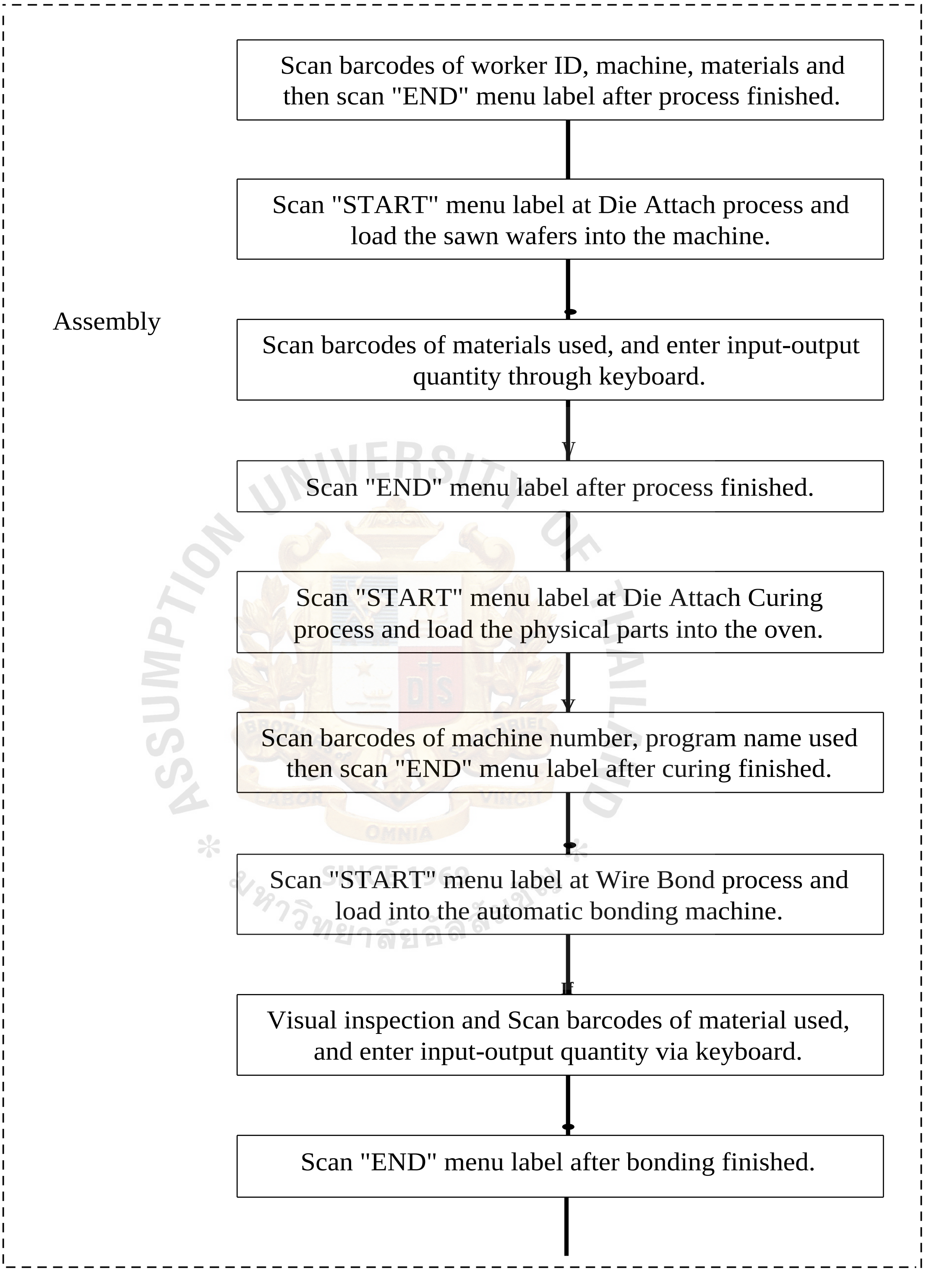



Figure 4.4. MTAI Manufacturing Procedure via the Proposed System. (Continued)

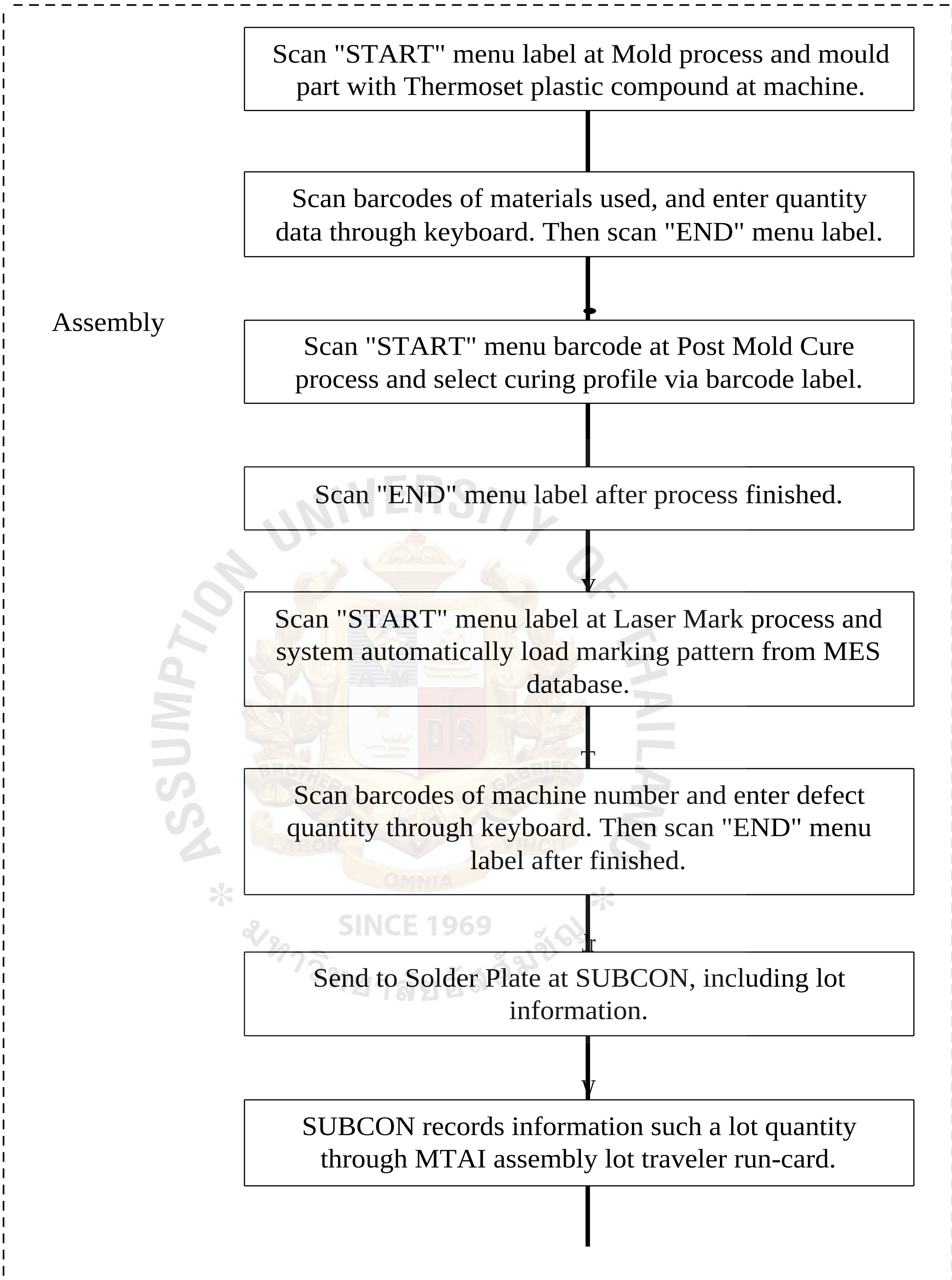



Figure 4.4. MTAI Manufacturing Procedure via the Proposed System. (Continued)

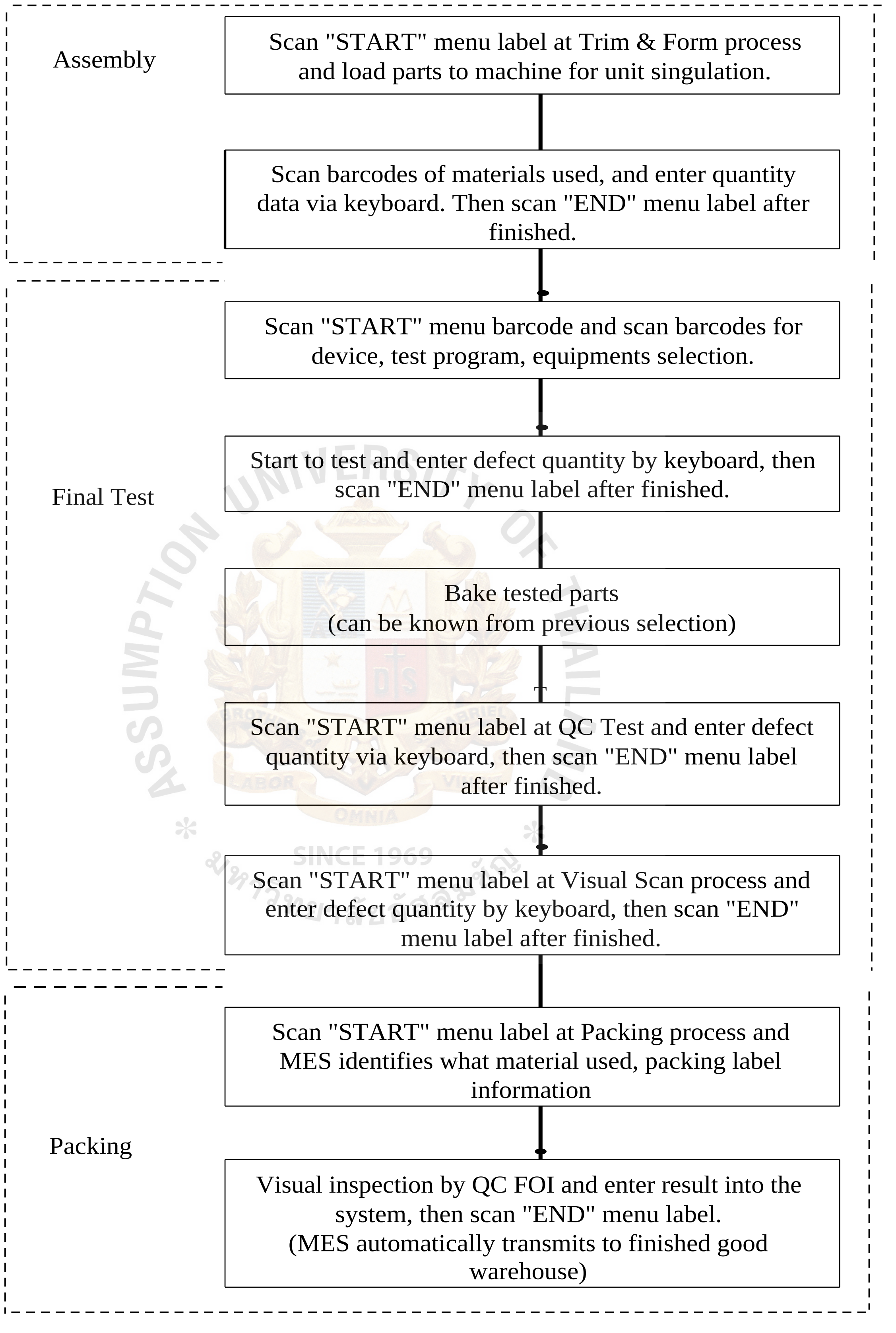



Figure 4.4. MTAI Manufacturing Procedure via the Proposed System. (Continued)

From the above manufacturing flow diagram, there is no significant difference between the number of steps of the existing system and the proposed one. Although the proposed system still uses many steps to run the manufacturing, the product data or information while production produced is more accurate than the existing one because there is an up-to-date data in the database system so everyone will use the same information to produce the parts.

The MTAI existing systems (manual, BA-WIP, PDC, SPC) will be a part of MES. Anyway MES provides subsystems such as cost accounting and finance system, utilization management system, Finished Goods Handing System (FGHS), etc. that this project report will not focus on those subsystems.

Therefore the MES reduces paperwork, human errors, and improve cycle time, while expediting the manufacturing processes. All data associated with a batch record can be consolidated in the system. It is no longer necessary to compile paperwork from production, QA department. The total in-house cycle time of manufacturing taken will be two days average.

To assess the proposed system, the elaborated feasibility study will also be provided in next section.

# V. FEASIBILITY ANALYSIS

This section demonstrates both quantitative and qualitative techniques for analysis and decision making.

## 5.1 Qualitative Analysis

The MES system can be analyzed in its direct and indirect benefits in the qualitative basis as follows:

(1) Eliminate tedious tasks such as data recording on each process, lot quantity verification before start next process, defect recording, etc.

(2) Shorten cycle time for total processes.

(3) Minimize paperwork in processes.

(4) Accurate and trustable report provided.

(5) Eliminate the reworking process.

(6) Utilize the machines to support production loading.

(7) Enhance know-how for production workers.

(8) Save time for data traceability and tracking.

(9) User-friendly system provided.

## 5.2 Economic Feasibility

### 5.2.1 Breakeven Analysis

This is a simple method for decision making in short term of economy concentrating on the relationship between revenue and cost to find out whether this investment is going to get the profit, this definition is shown as follow:

Profit = Revenue — Total Cost

And the total cost usually depends on customer demands, season, and other parameters so this may be linear or non-linear relation of revenue and cost. So this will not be easy to draw the shape of relation.

Anyway, to make calculation easily, this project uses company's income statement as shown in Appendix C (Figure C.1) to help for analysis.

(1) Cost of hardware includes:

(a) Computer Desktops are installed about 350 machines at each MTAI manufacturing process and this number equally the quantity of manufacturing machines. The investment cost per unit is $850 US so amount cost is 350 x 850 = $297,500 US.

(b) Servers are required 3 machines for two database servers and one application server. The server cost is $12,014 US per unit so amount cost is 3 x 12,014 = $36,042 US.

(c) Barcode Scanners are installed 350 machines at particular manufacturing machine. Each scanner cost is $100 US so the amount cost is equal to 350 x 100 = $35,000 US.

(d) 3 printers are installed and the cost is $350 US per machine so amount of printer cost is 3 x 350 = $1,050 US.

(e) Other accessories are used for installation and total cost is $48,405 US.

(2) Cost of software includes FACTORYworks and Xsite program. So the amount cost is $550,800 US.

The initial investment cost is combination of hardware cost plus software cost; hence the sum of total cost is equal to:

Initial cost = 297,500 + 36,042 + 35,000 + 1,050 + 48,405 + 550,800

= $968,797 US at beginning investment

If we assume that the revenue is still equal to net sales and the total cost consolidates cost of sales plus operating expenses and initial MES investment cost; then,

Revenue = $651,462,000 US.

Total Cost = cost of sales + operating expenses + initial cost

= 299,227,000 + 177,318,000 + 968,797

= $477,513,797 US.

Profit = 651,462,000 - 477,513,797

= $173,948,203 US.

= 173 Million $ US.

Moreover, MTAI spends six working days per week for mass production so the revenue average per day is 651,462,000 / (6x52) = $2,088,019.23 US or 2.08 Million US dollars. So MTAI will recover the investment cost within one month. This consideration is done under condition of production volume, customer demand fixed and also product cost is not changed.

In conclusion, the MES project should be invested because MTAI still get the profit and also MTAI are able to recover within one month less.

5.2.2 Present-Worth Evaluation

For cost analysis of the proposed system includes hardware, software, maintenance, machine depreciation and administrative expenses. This analysis would be explained as follows:

(1) Hardware and accessories expenses

As the investment cost of all hardware and accessories (excluding software cost) has been determined and described as above and the total calculation number is $417,997 US at beginning investment.

Assumed that the proposed system has 15 years life span (the worst case), then the straight-line depreciation of all equipments is calculated in 15 years of lifetime. Hence, the depreciation of hardware is equal to 417,997 / 15 = $27,866.47 US per year.

(2) Software expenseis $550,800 US.

(3) Maintenance cost, this will be considered and started at year one. Approximately equal to $12,200 US per year

(4) Operating expenses such as salary, administrative cost are equal to $177,318,000 US. (this number refers from Figure C.1)

Apart from the cost, the revenue will come from net sales of the company. And this project is assumed that the net sales value is equal in 15 years life span. So the annual revenue approximate number is $651,462,000 US.

Also assumed an interest rate of 5 percent per year compound annually, we get:

$$
\begin{aligned}
\text{NPW (5\%)} &= 651{,}462 - (417.997 + 550.8) + 651{,}462 *(P/A, 1\%, 15) \\
&\quad - (12.2 + 27.866 + 177{,}318)*(P/A, 1\%, 15) \\
&= 651{,}462 - 968.797 + (651{,}462 \times 10.3797) \\
&\quad - (177{,}358.066 \times 10.3797) \\
&= 5{,}571{,}549.81 \text{ K \$ US.} \\
&= 5{,}571.55 \text{ Million \$ US.}
\end{aligned}
$$

From the cash flow of calculation which is shown in Figure 5.1, this can summarize and conclude that the MES project should be invested in Microchip Thailand because the net present worth is positive value.

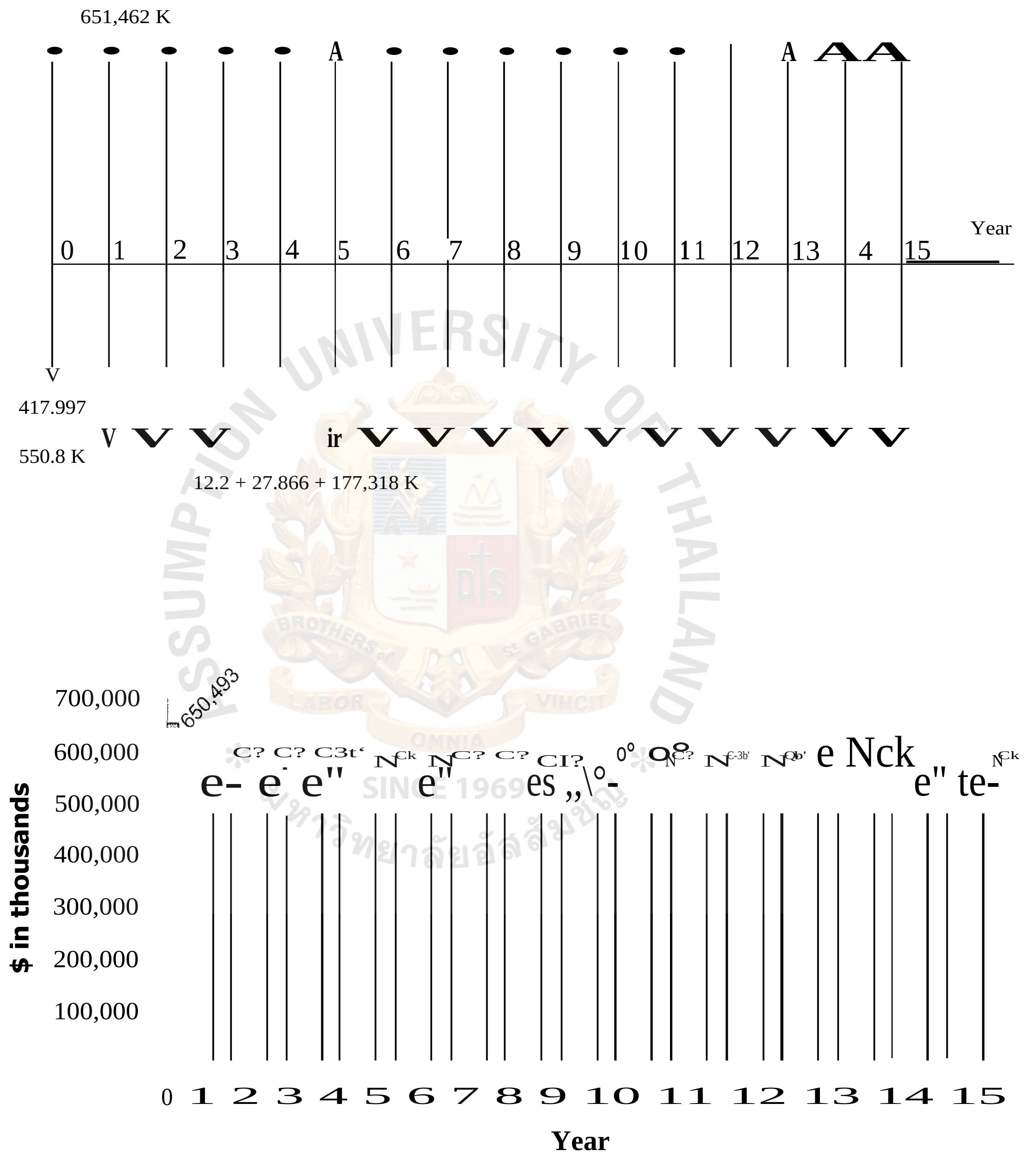



Figure 5.1. Cash Flow Diagram of the MES Investment.

Although the company will be in worst case situation, assumed that the net sales will be come down by 20 percent at beginning of year one and maintain the sales value until the 15th year, the company's cash flow will still be positive and the present worth will be equal to 4,219.16 Million $ US. This assumption is shown as Figure 5.2.

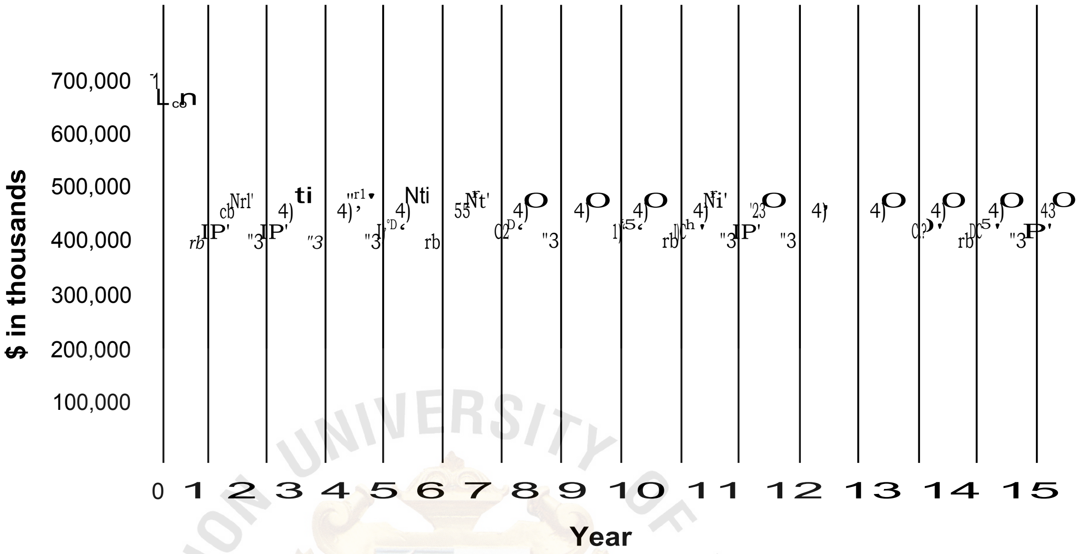



Figure 5.2. Cash Flow of Worst Case Situation.

## 5.3 Technical Feasibility

The proposed system is designed to meet the MTAI manufacturing's requirements. The MES must make production people be easier for using and operating in their activities. The data entry screen always updates the information without redundancy and no more double count or missing of inventory. Moreover, the network must be also installed to connect the Microchip worldwide sale offices. The proposed system can support the objectives and goals of Microchip Corporate including specification. Software and programs will also be designed to interface all components such as personal computers, bar code scanner reader, servers, printers, etc. All new hardware also is compatible with the FACTORYworks software system to support MES project.

There are five steps approach in developing system and application. The steps are as follows:

Step 1: Requirement Gathering & System Design Specification

This provides the framework for the MES project and defines a system of software/hardware architecture to meet MTAI objectives

Step 2: Functional Module Design

This phase is used to fine-tune each software component and provides a well-documented, software design, coding diagram including a detailed database model (DBMS table definition), software operational flow chart, written operating description and graphical user interface.

Step 3: Application Code Development

This serves as the system's supporting engineering documentation. Once coding is completed, this will also involve module testing for accuracy and functionality in stand alone manner. For example Graphical User Interface (GUI) is an application in this phase.

Step 4: Desktop Pilot

This phase allows the users to view the application prior to the facility installation. At this time, the system is approximately 85% complete and will be functionally demonstrated and simulated on all hardware in the manufacturing environment.

Step 5: System Integration

This testing phase will be performed after Desktop Pilot phase completed and this combines the individual software modules into a functional application.

According to the FACTORYworks automation software is designed by Brooks Automation Company to support MES project, the automation software allows their clients themselves can install and develop their own application software. However, there is limitation on their development so that it is protection of information flow that will be penetrated from unauthorized users.

The FACTORYworks will be separated in two sections; one application run on server and another run on client. UNIX Operating System would be selected to support all server applications whereas WINDOWS NT supports on terminal clients. Those two operating systems are stable and widespread that is the reason behind why MES chooses those operating systems. The LAN and internet also have been installed since there is internal and external communication via e-mail.

Moreover, MTAI have already been qualified QS-9000, ISO-9002 which are an international standard. Both standards require MTAI to do document and quality management so MTAI must have all kinds of working instruction, procedure, etc. Hence, this is an indirect benefit for MTAI because the programmers or even system analysts can take the documents to prepare and generate business rules and the Data Flow Diagram (DFD).

In conclusion, MTAI has facilities and infrastructure such as network system, document to prepare business rules and so on. Also there are clarified step approaches for system development. The FACTORYworks software would select the recognized operating systems on both client/server applications. All of these may guarantee that MTAI should invest on MES project.

**5.4 Operational Feasibility**

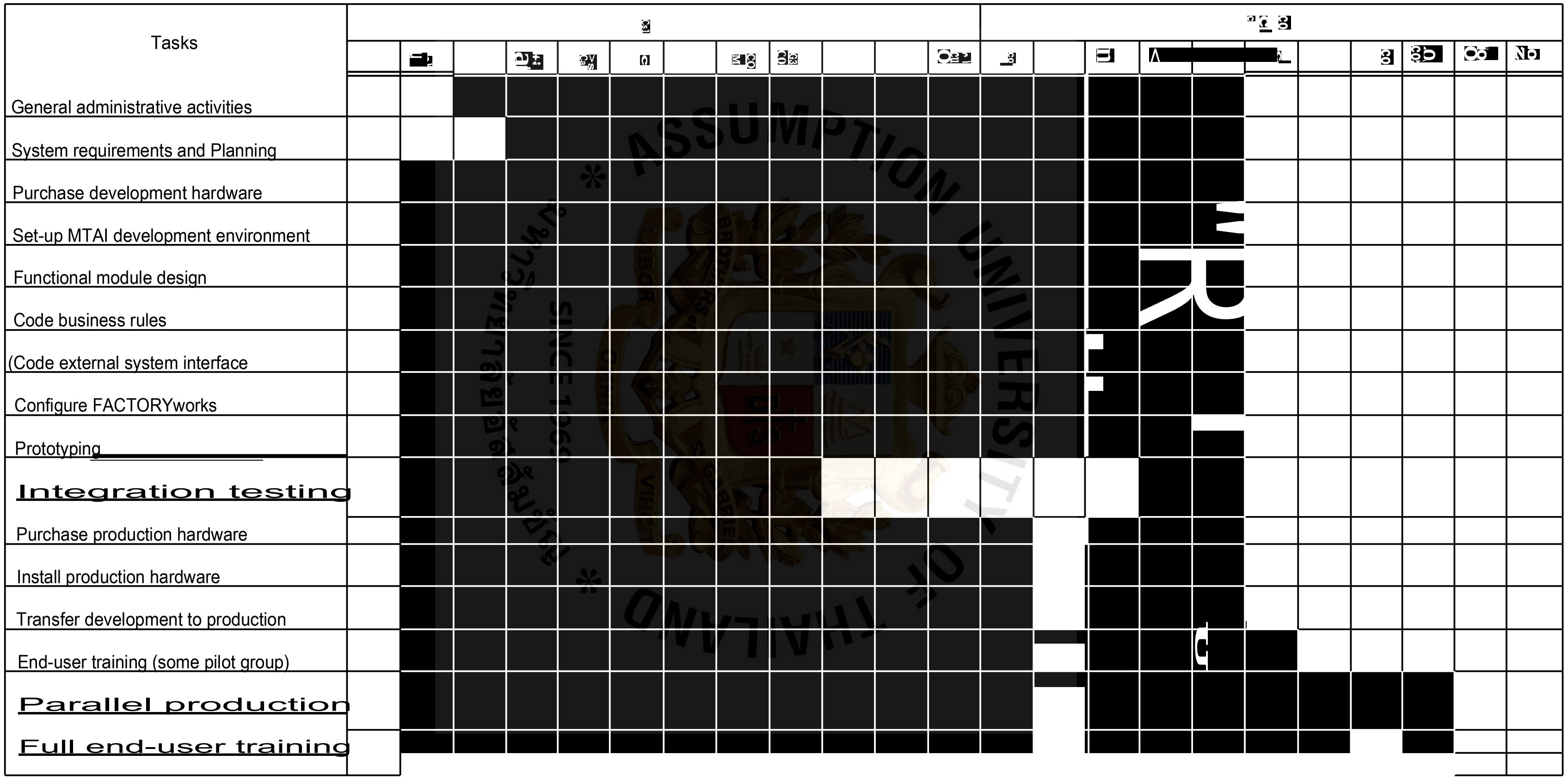
MTAI and Brooks Automation prepare the particular project team consists of four main people: a project manager, system engineers, software engineers and departmental representatives. The Figures 5.3 and 5.4 illustrate a project timeframe and all MES team members respectively. And each of these individuals has clearly defined roles and responsibilities that directly contribute to the success of MES project as follows:

(a) Project Manager has overall project responsibilities. His primary tasks include managing project costs to stay within budget, managing people and schedule to ensure on-time.

(b) System Engineers have responsibility for interfaces between Brooks Automation and other MTAI systems including third party software. The system engineers also responsible for requirement verification, documentation, acceptance testing associated with any hardware and software.

(c) Software Engineers have primary responsibility for the overall software design. They take an active role in detailed design, coding, testing and system integration.

(d) MTAI Departmental Representative is responsible for working hand to hand with system engineers and software engineers. Moreover, the representatives will be coordinators to communicate with manufacturing users for the right requirements gathering. This position came from a representative of each department to get involve the project and work closely with Brooks engineers.




MES Project Timeline.

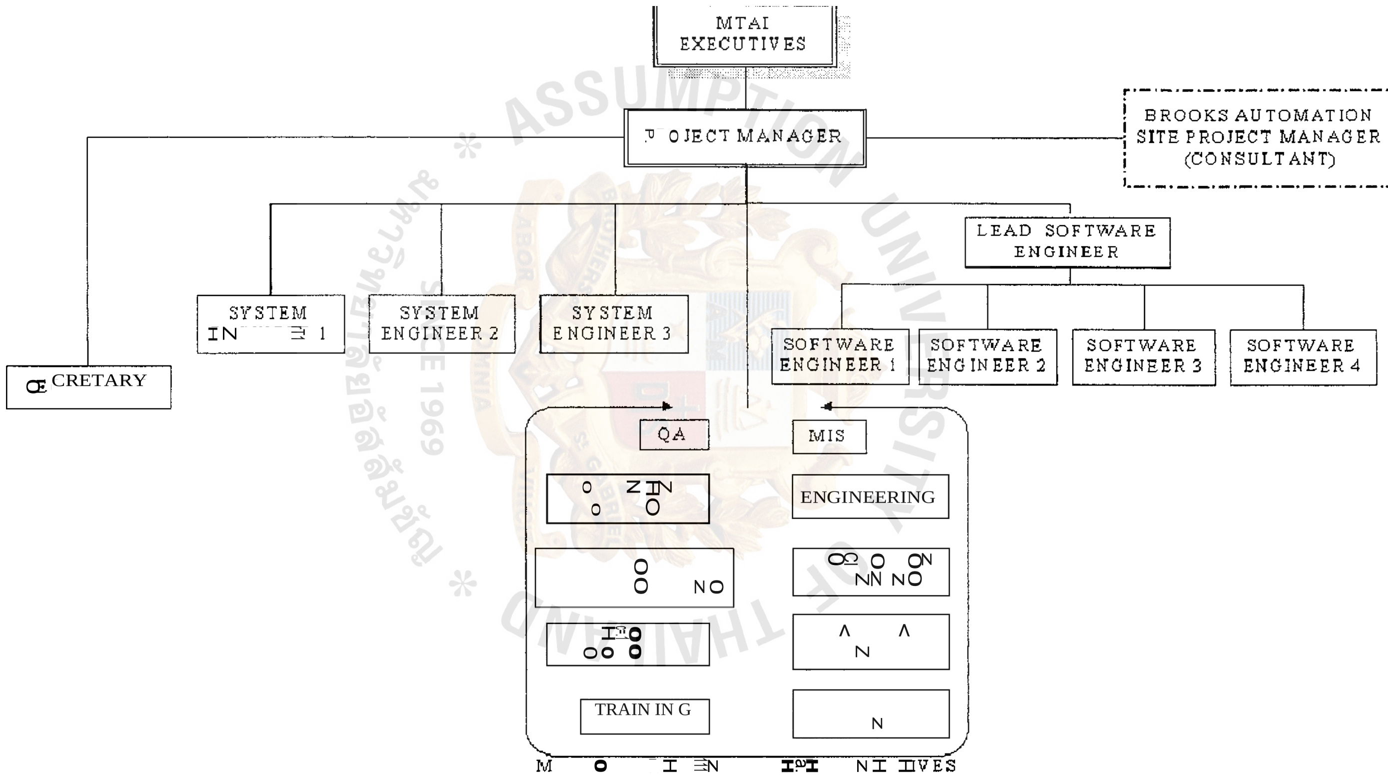



Figure 5.4. Organization Chart for MES Team.

Both system engineers and software engineers are Brooks Automation officials except a project manager. There is a weekly team meeting, the project manager will track the schedule and requirement related performance of each team member. If resources or requirement problems are identified at any time, the project manager has complete authority within the project to reorganize the team or reprioritize efforts to focus on specific problem areas. And all detailed status of performance against requirements, cost, and schedule will be reported by monthly basis.

In the aspect of system implementation, MTAI provides a training program for all production workers or other end-users. This is a significant component to enhance the manufacturing skill through MES software such as how to log on the system, how to track the history of product, how to move to next operation, and so on. Most of training materials are pictures of the actual screen display during manufacturing on shop floor, which are quite easy to understand and shown as Figure 5.5.

Therefore, MTAI are really interested in implementation of MES especially production and QA groups regarding the manufacturing procedure. Because they can easily get the report and information in the way that they require such as lot number, customer name, when the products produced, which machine has been used, etc. Hence, MTAI should implement the Manufacturing Execution System (MES).

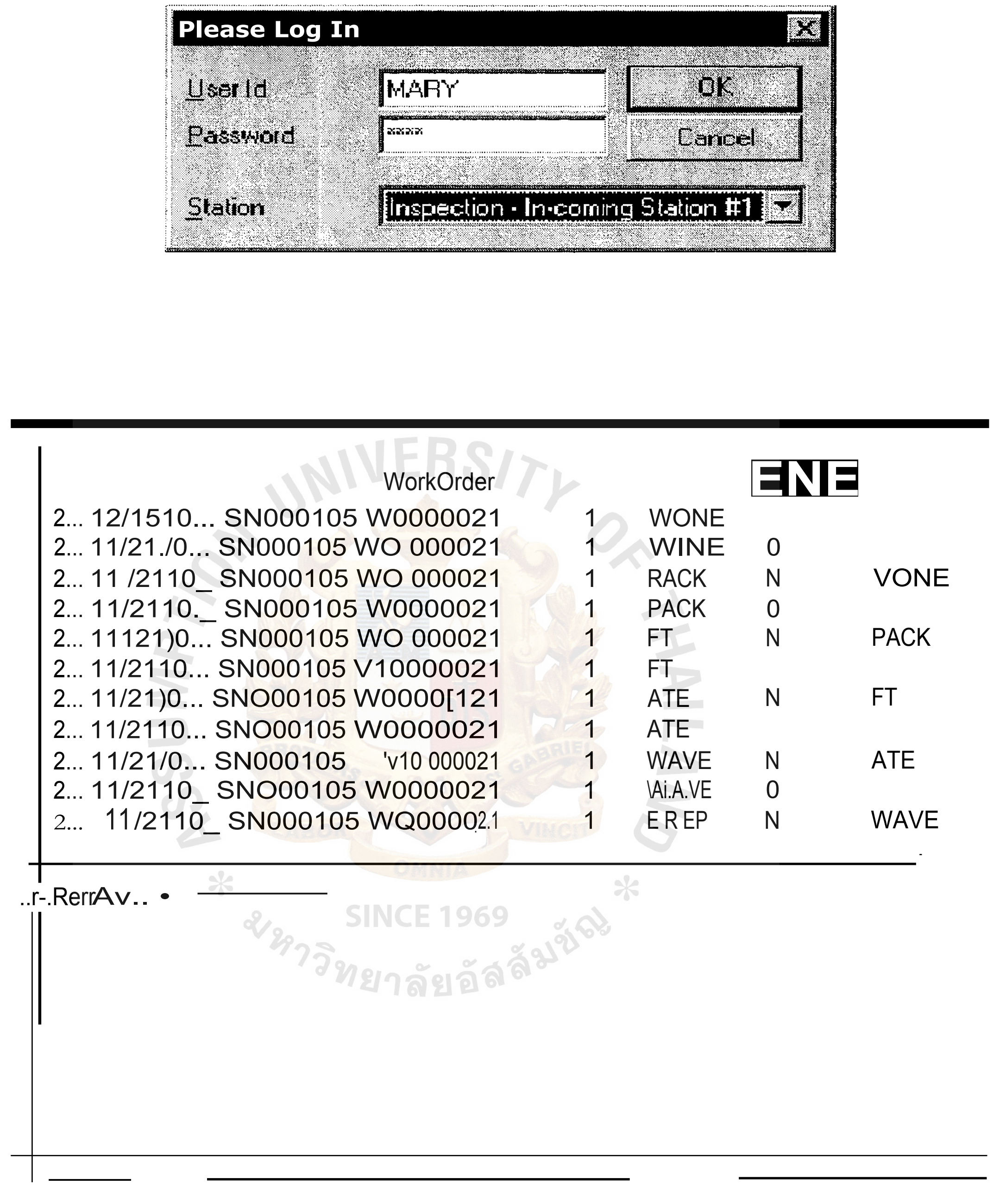



Figure 5.5. Example of Screen Display on Shop Floor via MES Software.

## 5.5 Time Measurement

From the new manufacturing procedure through MES, time measurement is used as a tool to support decision making. And this study requires a stopwatch for work measurement.

Regarding to the stopwatch time study, this project breaks down the manufacturing job into elements and then it was conducted a time study with a stopwatch and recorded each elemental time on particular activity. This project was determined to repeatedly measure only two times and compute the average time because of this study just wants to show how MES execute manufacturing processes to be faster than the existing one.

To easily calculate the time consumption of all processes, the estimated time taken would be applied for each activity as shown in Tables 5.1 and 5.2 by starting from the existing system and the proposed one respectively. The time study of all tasks will be illustrated in detailed calculation in Appendix D.

A few examples of time measurement will be shown as follows: the first task in Table 5.1 is BA-WIP system issue MPS and provides the request for manufacturing and this uses time for 4,050 seconds approximately. This activity includes requested data entry time, waiting time, printing document and load and move transaction to next process. The detail of calculation will be described below:

(1) Data entry time via BA-WIP = 417.60 seconds

(2) Waiting time = 2,073.00 seconds

(3) Time for printing document = 613.80 seconds

(4) Time for loading & transaction moving = 948.60 seconds

(5) Total is 417.60 + 2,073.00 + 613.80 + 948.60 = 4,053.00 seconds

4,050 seconds

Another example is "Do wafers inspection, verification and record results", is the third task of Table 5.1 that spends time 3,750 seconds. However this number came from the following calculation:

(1) 1 wafer uses 430.80 seconds for inspection. (1 batch = 8 wafers)

(2) Total time for inspection 430.80 x 8 = 3,446.40 seconds.

(3) Result recording spends 307.80 seconds.

(4) Total time usage for this task is 3446.40 + 307.80 = 3,754.20 3,750 seconds.

Therefore, the MES will help to reduce total time consumption by eliminating the manual working processes, data recording, key the data into computer again, etc. The percentage of time improvement is approximately 25%. This number will be shown how to calculate as follow:

Total time consumption of existing system = 152,180 seconds

Total time consumption of MES = 110,729 seconds

So percentage of time reduction $\dfrac{(152{,}180 - 110{,}729) \times 100}{152{,}180}$

$= 27.23\% \quad 25\%$

Table 5.1. Time Measurement of Manufacturing Procedure in the Existing System.

| No. | Activities | Time Taken (in seconds) |
|---|---|---|
| 1 | Issue assembly request document and loading per MPS | 4,050 |
| 2 | Issue AI and assembly lot traveler run-card | 2,960 |
| 3 | Do wafers inspection, verification and record results | 3,750 |
| 4 | Release wafers if acceptable | 610 |
| 5 | Load wafers into Mount & Saw machine | 770 |
| 6 | Cut size per drawing required creating by PDC system | 10,560 |
| 7 | Record quantity, saw blade part number, machine parameters, etc. into log sheet & run-card | 820 |

Table 5.1. Time Measurement of Manufacturing Procedure in the Existing System. (Continued)

| No. | Activities | Time Taken (in seconds) |
|---|---|---|
| 8 | Load the sawn wafers into Die Attach automatic machine | 1,010 |
| 9 | Pick and place die to leadframe | 11,000 |
| 10 | Record adhesive epoxy type, quantity, material part number, machine parameters, etc. into log sheet | 620 |
| 11 | Load into oven for curing | 520 |
| 12 | Record machine number, program profile name, etc | 670 |
| 13 | Put into Wire Bond automatic machine and start bonding | 15,440 |
| 14 | Visual inspect and record number of defects, bonding tool part number, quantity, etc. into log sheet | 7,220 |
| 15 | Mould part with Thermo set plastic compound | 4,550 |
| 16 | Record compound type, part number, lot quantity, etc. | 1,000 |
| 17 | Load the molded parts into oven for curing | 850 |
| 18 | Record machine number, time in-out, etc. into log sheet | 500 |
| 19 | Mark device name, manufacturer on the top & bottom package surface via laser mark equipment | 7,410 |
| 20 | Record lot quantity, number of defects found, machine number, etc. into log sheet | 620 |
| 21 | Send to solder plate at SUBCON, including lot information | 17,370 |
| 22 | SUBCON records information such a lot quantity through MTAI assembly lot traveler run-card | 920 |
| 23 | Load the solder plated parts to Trim & Form machine | 900 |
| 24 | Run unit singulation | 4,200 |
| 25 | Record number of defects, tooling part number, quantity, etc. into log sheet | 1 200 |
| 26 | Create test lot traveler run-card | 3,510 |
| 27 | Select test program and equipments and start to test | 9,580 |
| 28 | Record test program name, lot quantity, defects, etc. into test lot traveler run-card | 930 |
| 29 | Bake the tested parts (optional) | 22,540 |
| 30 | QC sampling test | 5,230 |
| 31 | QC records test program, sampling quantity, etc | 880 |
| 32 | Production load parts to visual scanning machine | 8,940 |
| 33 | Record lot quantity, defects, etc. into test lot traveler run-card | 1,050 |
| | **Total time taken (seconds)** | **152,180** |

Table 5.2. Time Measurement of Manufacturing Procedure in the Proposed System.

| No. | Activities | Time Taken (in seconds) |
|---|---|---|
| 1 | Receive wafers from FAB sites including its information | 680 |
| 2 | Start to load per request via bar code "START" menu then the system automatically issues related documents | 570 |
| 3 | Do wafers inspection, records result by scanner reader | 3,550 |
| 4 | Release wafers by bar code "ACCEPT" menu | 40 |
| 5 | Scan "START" label for Mount & Saw process | 25 |
| 6 | Load the physical wafers to machine | 780 |
| 7 | Scan barcode i.e. worker ID, information, parameters | 75 |
| 8 | Start machine for running | 10,150 |
| 9 | Scan "END" after finished process | 20 |
| 10 | Scan "START" label for Die Attach process | 20 |
| 11 | Load wafers into Die Attach machine and running | 12,020 |
| 12 | Scan barcode i.e. worker ID, material information, machine parameters | 95 |
| 13 | Scan "END" after finished process | 27 |
| 14 | Scan "START" label for Die Attach Curing process, and load automatically a curing profile | 24 |
| 15 | Load physical parts into oven & start curing | 605 |
| 16 | Scan barcode i.e. worker ID, program name, machine number | 140 |
| 17 | Scan "END" after finished process | 20 |
| 18 | Scan "START" label for Wire Bond process and load to machine | 915 |
| 19 | Start machine for running and visual inspect on physical parts | 20,780 |
| 20 | Scan barcode i.e. worker ID, material used, machine number, enter input-output via keyboard | 135 |
| 21 | Scan "END" after bonding finished | 30 |
| 22 | Scan "START" label at Mold process and load to machine | 1,772 |
| 23 | Start machine running | 2,840 |
| 24 | Scan barcode i.e. worker ID, material used, machine number, enter input-output via keyboard | 215 |
| 25 | Scan "END" after molding finished | 23 |
| 26 | Scan "START" label at Post Mold process, load to machine and select curing profile name | 1,045 |

Table 5.2. Time Measurement of Manufacturing Procedure in the Proposed System. (Continued)

| No. | Activities | Time Taken (in seconds) |
|---|---|---|
| 27 | Scan "END" after post cure molding finished | 25 |
| 28 | Scan "START" label at Laser Mark process, load to machine. | 1,340 |
| 29 | Scan barcode i.e. worker **ID,** material used, machine number, defect quantity, enter input-output via keyboard | 140 |
| 30 | Scan "END" after marking finished | 24 |
| 31 | Ship to SUBCON for solder plating | 16,450 |
| 32 | SUBCON records information through run-card | 980 |
| 33 | Scan "START" label at Trim & Form process and load physical units to machine. | 935 |
| 34 | Scan barcode i.e. worker ID, material used, machine number, and "END" after finished | 180 |
| 35 | Scan "START" label at Final Test process, and select testing program, equipment then load into the machine. | 1,310 |
| 36 | Start to test and record defect quantity via keyboard and scan "END" label when process completed | 255 |
| 37 | Bake the tested parts (optional) | 20,050 |
| 38 | Scan "START" label at QC Sampling Test process, and select testing program, equipment then load into the machine. | 3,395 |
| 39 | Scan "END" after QC sampling finished | 34 |
| 40 | Scan "START" label at Visual Scan process, and select product type, equipment then load into the machine. | 8,990 |
| 41 | Scan "END" after scanning finished | 25 |
| | **Total time taken (seconds)** | **110,729** |

# VI. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

Manufacturing Execution System (MES) is an on-line computerized system which is combination of tools and methods to succeed manufacturing activities. It helps to fulfill the critical gap between an organization's top-level supply chain management, Enterprise Resource Planning (ERP), sale management, product & process engineering systems, and the plant floor.

One of the most important features of the MES is the emphasis of paperless manufacturing that is used to reduce the paperwork in production floor and ensure data accuracy during transaction occurred.

The MES is developed from a computer software that used the information of inspection report, receiving report, Statistical Process Control (SPC) and whatever for execution the manufacturing plan through device control systems such as machine, robot, tool storage, conveyor, etc.; hence, the MES solution is between planning layer and device control layer.

MES can be divided into two functional parts: core functions and support functions. Core functions are interrelated and basic to most production systems. The support functions do not deal primarily with the actual management of the work orders and the manufacturing resources. These support functions are no less important, but they seem one dimension removed from production. And they can be any number of functions, and new ones are sure to be developed in the future.

Furthermore, all system functions as the central depository for data distribution and collection for all other enterprise systems.

Many organizations are shifting their existing methodology to be MES approach because they have seen that the MES concept helps them to be paperless manufacturing and provide the real-time functionalities.

According to an existing working system of manufacturing department at Microchip Technology, Thailand (MTAI) is carried out manually and routinely, this will cause a lot of paper documents, with no information accuracy. It is also difficult to keep and find data, difficult to update data immediately due to data is not linked with database). Further, it also takes time in manufacturing processes.

Therefore, MTAI has attempted to improve its working system in order to make better working system and reduce unnecessary tasks.

It also realizes the importance of MES which can help to solve such existing problems. Since it can contain a lot of data, it can reduce paper documents and it also improves data accuracy. Moreover, the data is easy to be updated and this system can work on-line application and can be used with other sectors as well.

Thus, MTAI begins to apply MES to an existing system in manufacturing department which starts analyzing the existing system and define system requirements. And the outcome illustrates that the manufacturing procedure will take so much time for data recording manually on individual process such as batch information, product type, defect quantity, and so on. Further, the workers have to key in recorded data into a computer system so there is possibility to happen wrong data entry. The total cycle time for manufacturing will be taken 3 days starting from MTAI Wafer/Die Bank until Final Test operation finished.

The MES is customized and designed to minimize paper works in processes as above mention. It is easy to execute and monitor the manufacturing's activities. Since every step must be verified and tracked by network that is data transaction passing through the LAN and WAN system.

Later, the feasibility analysis of MES is conducted to analyze the qualitative and quantitative basis including economic feasibility, technical feasibility and operational feasibility. In addition, the present worth will support the idea of returned value that is more than worthwhile for each year after establishing the proposed system.

Finally, the proposed system will be subject to the modification on the manufacturing procedure. The clients and all concerned people who need to use the system must be provided and supported with the training program of MES knowledge and how to use and operate the system. If the implementation plan is successful, the manufacturing department at MTAI will experience reduced manual working process, reduced cycle time, product tracking and traceability. Moreover it will increase on-time delivery and provide a higher overall level of efficiency.

## 6.2 Recommendations

This project towards a system analysis and design method is likely to be useful for organization that needs to improve and develop the workers satisfaction and performance towards work or to solve the manual working processes such as data collection, data recording, information transferred, etc. that are tedious and inefficient. However it can also be applied in other industries such as for chemical plants, automotive manufacturers, food processing companies, etc that perform the similar working environments. Most manufacturing companies are required to make optimum use of resources and must consider many variables in the daily operation of manufacturing facility.

The result of this study indicates that MES at manufacturing, Microchip Thailand is useful to working process system and its application leads to the systematic system.

Since the application of only one section of the company is not enough to generate the full capacity for total operations, developing overall areas of company will bring up the efficient working processes to achieve higher effectiveness in the large scale of the company.

Although Microchip has a fully integrated manufacturing facility, beginning from wafer fabrication to final electrical testing, only assembly packaging and electrical testing area will be implemented in the MES. Therefore the wafer fabrication factories and the global sale and engineering offices would also be recommended to implement the system because of the MES provides enhancement of the systematical manufacturing processes and formalization of production methodologies and procedures into an integrated computer system. Thus the whole picture of Microchip company will be continuous improvement, employee involvement through teams and other methods of empowerment including the decision making information will be improved such as materials and resources planning, inventory management, and so on.

In conclusion, MES can play a major role in creating a more agile manufacturing company. And the system provides for the immediate information presenting the most meaningful way brings an improved focus to production problems. Moreover, the MES can provide more data, more timely, more accurately and more consistently to more people.

According to the limitation of time frame, an implementation of this project is not completely conducted to obtain the result of method application. Therefore, a better result shall be provided for more details from other sources.

# APPENDIX A

## ASSEMBLY PACKAGING AND TEST PROCESS FLOW

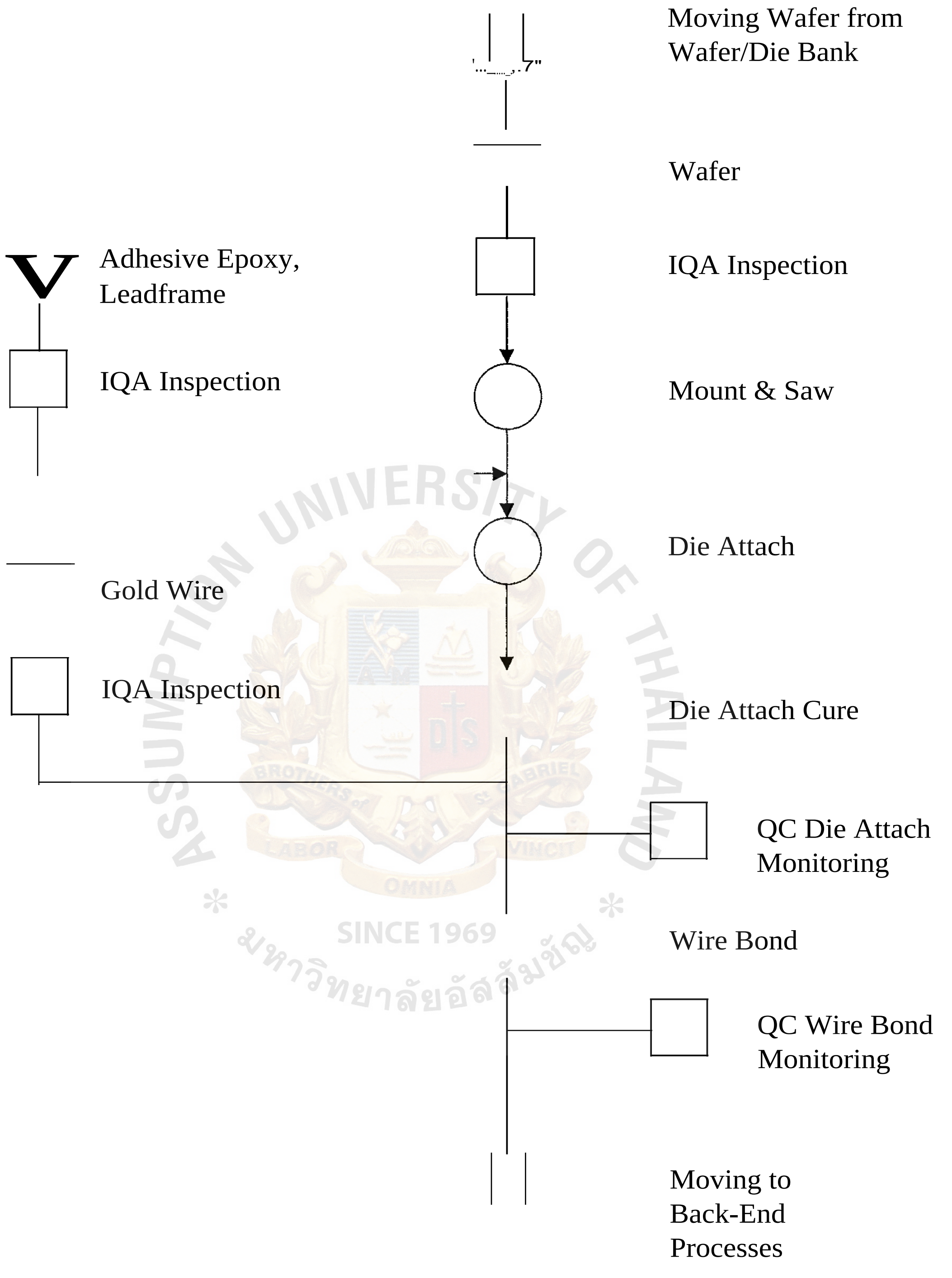



Figure A.1. Front-End Assembly Flow Chart.

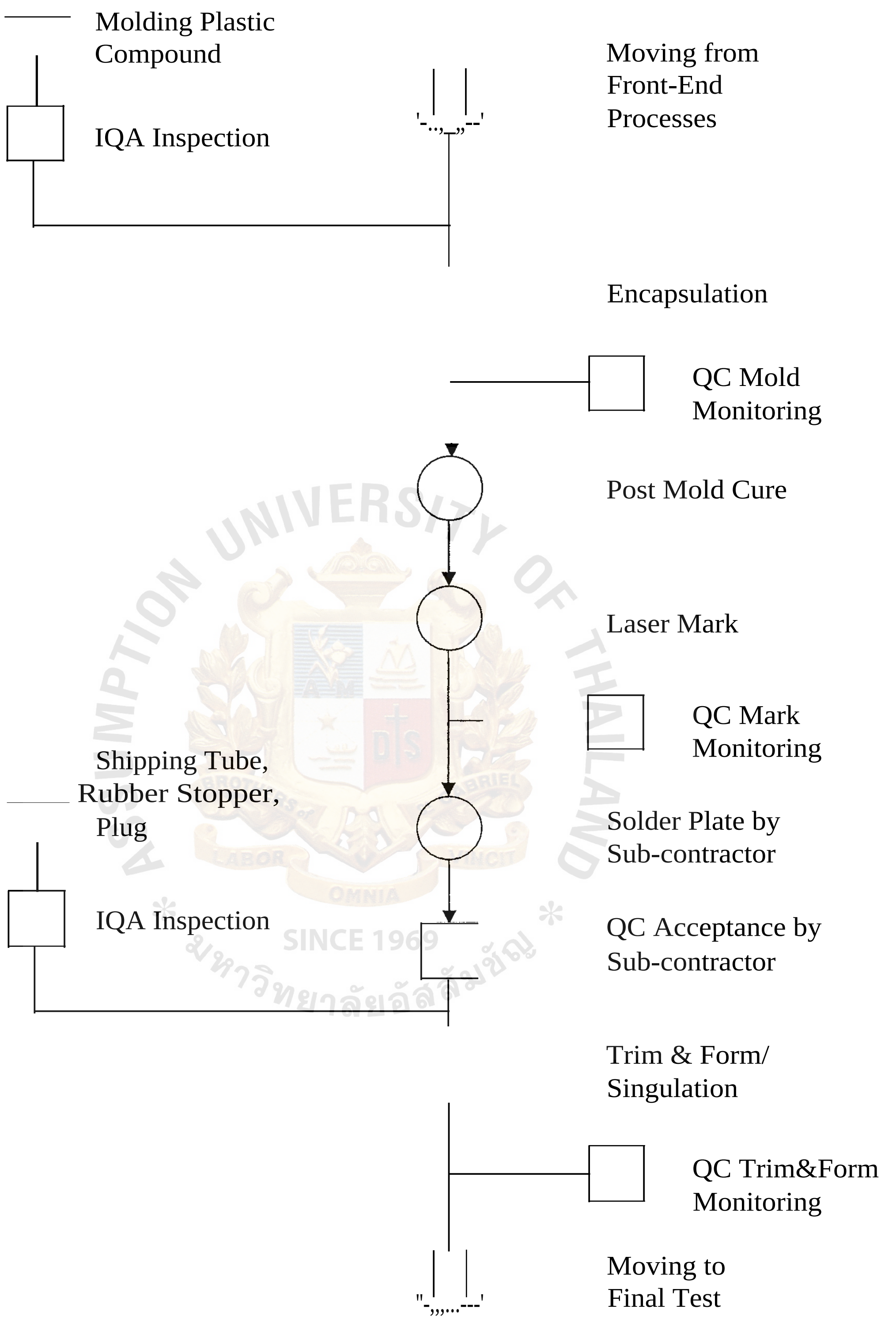



Figure A.2. Back-End Assembly Flow Chart.

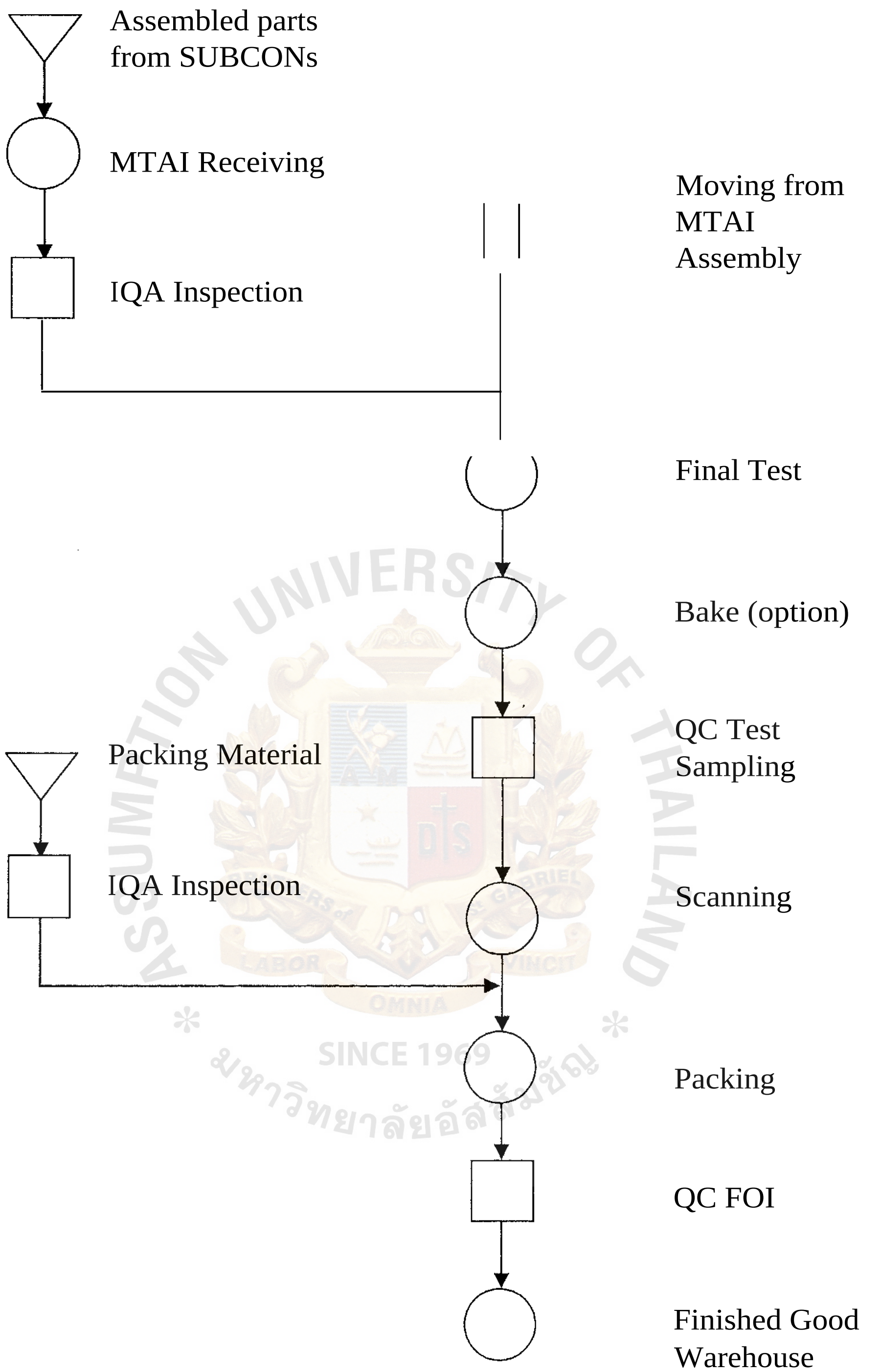



Figure A.3. Final Test Flow Chart.

APPENDIX B

IC COMPONENT DETAILS

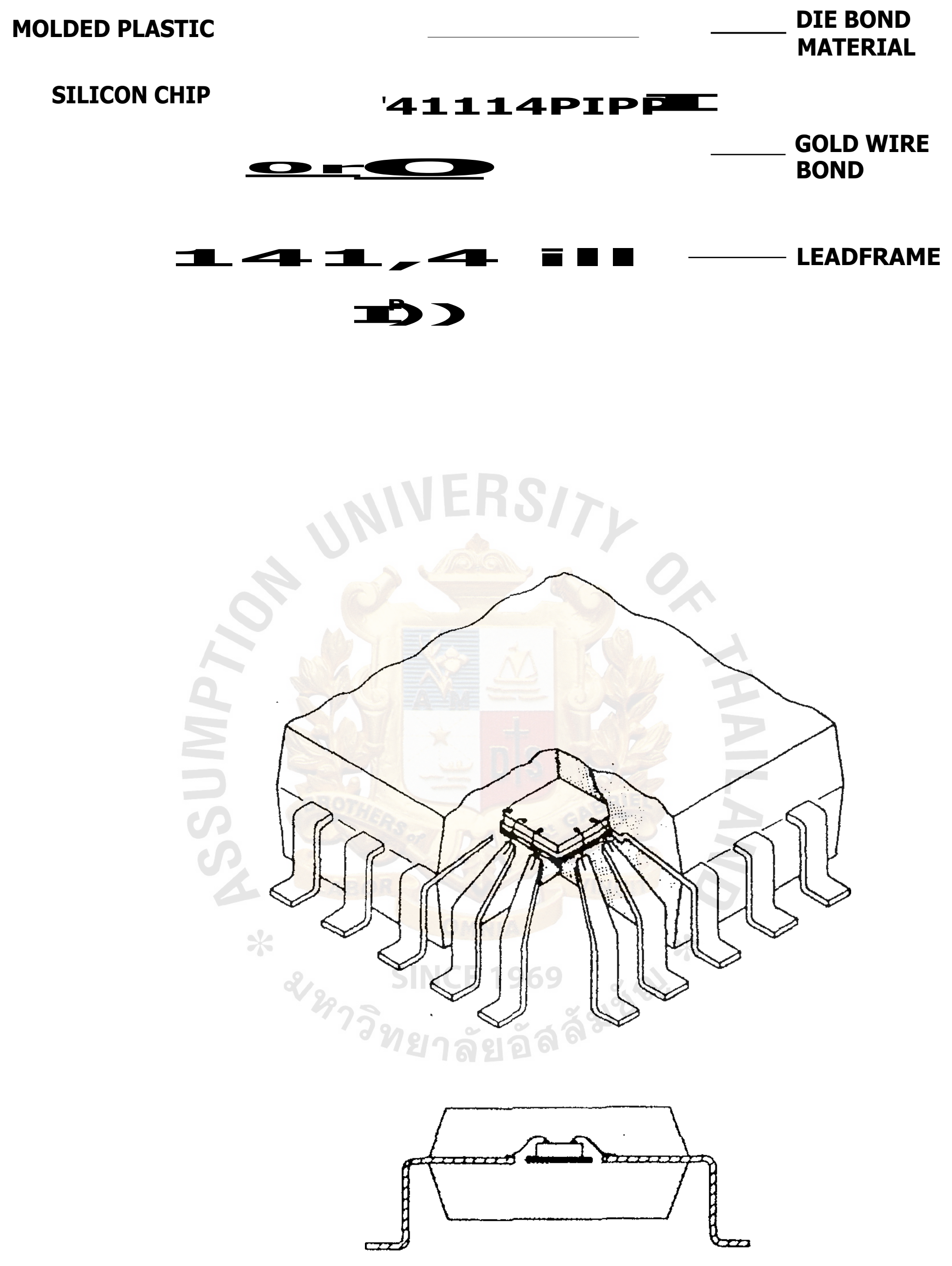



Figure B.1. Cutaway View of IC Plastic Package (Hill 1990).

APPENDIX C

INCOME STATEMENT OF MICROCHIP INCORPORATED
AT FISCAL YEAR 2003

MICROCHIP TECHNOLOGY INCORPORATED AND SUBSIDIARIES
CONDENSED CONSOLIDATED STATEMENT OF INCOME

(Unaudited)
(in thousands except per share amounts)

| | Qtr. Ended 6/30/02 | Qtr. Ended 9/30/02 | Qtr. Ended 12/31/02 | Qtr. Ended 3/31/03 | Fiscal Year 2003 |
|---|---|---|---|---|---|
| Net sales | $157,544 | $166 ,776 | `$167,474 | $159,666 | $ 651,462 |
| Cost of sales | 75 177 | 76,478 | 74.580 | 72 992 | 299.227 |
| Gross profit | 82,367 | 90,300 | 92,894 | 86,674 | 352,235 |
| Operating expenses: | | | | | |
| Research and development | 21 ,560 | 22 ,337 | 22 ,323 | 21,743 | 87 ,963 |
| Selling, general and administrative | 21.941 | 23.127 | 22.430 | 21,657 | 89 355 |
| | 43,501 | 45,464 | 44,753 | 43,600 | 177,318 |
| Operating income before special charges | 38,866 | 44,836 | 48,141 | 43,074 | 174,917 |
| Fab 3 impairment charge | 0 | 41 ,500 | 0 | 0 | 41,500 |
| In process research & development charge | 9 300 | | | | 9.300 |
| Operating Income | 29,566 | 3,336 | 48,141 | 43,074 | 124,117 |
| Other income, net | 1 250 | 1 153 | 540 | 1 272 | 4 215 |
| Income before income taxes | 30,816 | 4,489 | 48,681 | 44,346 | 128,332 |
| Income taxes | 10 057 | (5.0071 | 12 299 | 11 308 | 28 657 |
| Net income before special charges and cumulative effect of change in accounting principle | 30,059 | 34,396: | 36,382 | 33,038 | 133,875 |
| Net income before cumulative effect of change in accounting principle | 20,759 | 9,496 | 36,382 | 33,038 | 99,675 |
| Cumulative effect of change in accounting principle | 11 443 | | | 0 | 11,443 |
| Net income | $ 9 316 | $ 9,496 | $ 36,382 | $ 33,038 | $ 88,232 |
| Basic net income per share before special charges and cumulative effect of change in accounting principle | $ 0.15 | $ 0.17 | $ 0.18 | $ 0.16 | $ 0.66 |
| Basic net income per share | $ 0.05 | $ 0.05 | $ 0.18 | $ 0.16, | $ 0.44 |
| Diluted net income per share before special charges and cumulative effect of change in accounting principle | $ 0.14 | $ 0.16 | $ 0.17 | $ 0.16 | $ 0.64 |
| Diluted net income per share | $ 0.04 | $ 0.05 | $ 0.17 | $ 0.16 | $ 0.42 |
| Basic shares used in calculation | 201 292. | 202 047 | 203,109 | 203,496 | 202.483 |
| Diluted shares used in calculation | 211 527 | 209,642 | 210.929 | 210,843 | 210.646 |

Figure C.1. Income Statement of Microchip Incorporated at Fiscal Year 2003.

# APPENDIX D

# TIME STUDY FOR MTAI MANUFACTURING

The following is time study which demonstrates the detail of time usage and how to calculate the time on both existing and proposed system. The numbers in the table have been measured by stopwatch.

Table D.1. Time Study of All Tasks in Existing Manufacturing System.

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 1 | Issue assembly request document and loading per MPS | | | |
| | a) Data entry time via BA-WIP | 413.00 | 417.60 | |
| | b) Waiting time | 2,103.30 | 2,073.00 | |
| | c) Time for printing | 600.50 | 613.80 | |
| | d) Time for loading / transaction moved | 930.50 | 948.60 | |
| | e) Total time =a+b+c+d | 4,047.30 | 4,053.00 | 4,050 |
| 2 | Issue AI and assembly lot traveler run-card | | | |
| | a) Data entry time | 244.40 | 253.80 | |
| | b) Waiting time for program response AI, run-card | 1,840.60 | 1,946.40 | |
| | c) Time for printing | 870.80 | 763.80 | |
| | d) Total time = a + b + c | 2,955.80 | 2,964.00 | 2,960 |
| 3 | Do wafers inspection, verification and record results | | | |
| | a) Inspection time for one wafer (1 batch = 8 wafers) | 412.50 | 430.80 | |
| | b) Inspection time for one batch | 3,300.00 | 3,446.40 | |
| | c) Time for result recording | 438.00 | 307.80 | |
| | d) Total time = b + c | 3,738.00 | 3,754.20 | 3,750 |
| 4 | Release wafers if acceptable | | | |
| | a) Transaction move | 613.00 | 608.40 | 610 |
| 5 | Load wafers into Mount & Saw machine | 740.80 | 767.40 | 770 |
| 6 | Cut size per drawing required creating by PDC system | | | |
| | a) Recall program and database from PDC | 974.00 | 981.60 | |
| | b) Run machine by cutting blade controlling with motor | 9,608.50 | 9,576.00 | |
| | c) Total time = a + b | 10,582.50 | 10,557.60 | 10,560 |

Table D.1. Time Study of All Tasks in Existing Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 7 | Record quantity, blade part No, machine parameters, etc. into log sheet, run-card | 827.80 | 820.20 | 820 |
| 8 | Load the sawn wafers into Die Attach automatic machine | 1,017.50 | 1,009.20 | 1,010 |
| 9 | Pick and place die to leadframe | | | |
| | a) Epoxy writing time | 7,102.00 | 7,086.00 | |
| | b) Pick & place die for one batch | 3,890.20 | 3,919.80 | |
| | c) Total time = a + b | 10,992.20 | 11,005.80 | 11,000 |
| 10 | Record adhesive epoxy type, quantity, material part number, machine parameters, etc. into log sheet | 614.60 | 627.00 | 620 |
| 11 | Load into oven for curing | 524.30 | 519.00 | 520 |
| 12 | Record machine number, profile name, etc | 663.50 | 675.60 | 670 |
| 13 | Put into Wire Bond automatic machine and start bonding | | | |
| | a) Time for in-load | 885.50 | 903.00 | |
| | b) Bonding time for one batch | 14,545.00 | 14,536.80 | |
| | c) Total time = a + b | 15,430.50 | 15,439.80 | 15,440 |
| 14 | Visual inspect and record defects, bonding tool part number, quantity, etc. into log sheet | | | |
| | a) Sampling every 15 minutes during bonding time | | | |
| | # sampling = bonding time/15 =242.30/15 = 16.15 times | | | |
| | 1 sampling for inspection uses | 390.40 | 388.20 | |
| | Time for visual inspection one batch | 6.304.96 | 6,269.43 | |
| | b) Recording time | 923.50 | 950.40 | |
| | c) Total time = a + b | 7,228.46 | 7,219.83 | 7,220 |
| 15 | Mould part with Thermo set plastic compound | | | |
| | a) Time for in-load & un-load | 1,650.50 | 1,721.40 | |
| | b) Machine cycle for one batch | 2,904.50 | 2,827.20 | |
| | c) Total time = a + b | 4,555.00 | 4,548.60 | 4,550 |
| 16 | Record compound type, part number, lot quantity, etc. | 996.70 | 1,000.80 | 1,000 |
| 17 | Load the molded parts into oven for curing | 846.00 | 853.20 | 850 |
| 18 | Record machine number, time in-out, etc. into log sheet | 498.50 | 504.60 | 500 |

Table D.1. Time Study of All Tasks in Existing Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 19 | Mark device name, manufacturer on the top & bottom package surface via machine | | | |
| | a) Time for in-load & un-load<br>b) Load marking program<br>c) Machine cycle for one batch<br>d) Total time = a + b + c | 1,110.60<br>1,705.40<br>4,598.00<br>7,414.00 | 1,088.40<br>1,756.80<br>4,566.60<br>7,411.80 | 7,410 |
| 20 | Record lot quantity, number of defects found, machine number, etc. into log sheet | 625.50 | 617.40 | 620 |
| 21 | Send to solder plate at SUBCON | | | |
| | a) Printing packing list & other documents<br>b) Transportation time (round trip)<br>c) Plating machine cycle for one batch<br>d) Total time = a + b + c | 1,129.00<br>13,083.00<br>3,150.50<br>17,362.50 | 810.60<br>13,483.20<br>3,081.60<br>17,375.40 | 17,370 |
| 22 | SUBCON records information such a lot quantity through MTAI assembly lot traveler run-card | 913.70 | 925.20 | 920 |
| 23 | Load the solder plated parts to Trim & Form machine | 918.00 | 898.20 | 900 |
| 24 | Run unit singulation | 4,186.50 | 4,203.00 | 4,200 |
| 25 | Record number of defects, tooling part number, quantity, etc. into log sheet & move transaction to test process | 1,220.00 | 1,197.60 | 1,200 |
| 26 | Create test lot traveler run-card | | | |
| | a) Pull data from assembly<br>b) Time for printing run-card<br>c) Total time = a + b | 2,795.40<br>695.00<br>3,490.40 | 2,835.60<br>676.80<br>3,512.40 | 3,510 |
| 27 | Select test program, equipment for testing | | | |
| | a) Choose test program, equipment from database<br>b) Start testing<br>c) Total time = a + b | 2,927.20<br>6,639.00<br>9,566.20 | 2,710.20<br>6,875.40<br>9,585.60 | 9,580 |
| 28 | Record test program name, lot quantity, defects, etc. into test lot traveler run-card | 939.50 | 926.40 | 930 |

Table D.1. Time Study of All Tasks in Existing Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 29 | Bake the tested parts (optional) | | | |
| | a) Time for in-load & un-load | 915.00 | 937.80 | |
| | b) Baking time | 21,620.50 | 21,606.60 | |
| | c) Total time = a + b | 22,535.50 | 22,544.40 | 22,540 |
| 30 | QC sampling test | | | |
| | a) Select test program | 2,221.40 | 2,249.40 | |
| | b) Start testing | 3,004.20 | 2,985.00 | |
| | c) Total time = a + b | 5,225.60 | 5,234.40 | 5,230 |
| 31 | QC records test program, sampling quantity | 877.40 | 883.80 | 880 |
| 32 | Load parts to visual scanning machine | | | |
| | a) Time for in-load & un-load | 932.30 | 917.40 | |
| | b) Start machine cycle for one batch | 8,000.50 | 8,026.20 | |
| | c) Total time = a + b | 8,932.80 | 8,943.60 | 8,940 |
| 33 | Record lot quantity, defects, etc. into test lot traveler run-card | 1,056.40 | 1,047.60 | 1,050 |
| | **Total time taken** | **152,126.46** | **152,235.03** | **152,180** |

Table D.2. Time Study of All Tasks in Proposed Manufacturing System.

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 1 | Receive wafers from FAB sites | | | |
| | a) Data entry time via bar code reader | 38.40 | 52.40 | |
| | b) Waiting time for program response & do transaction | 645.00 | 624.50 | |
| | c) Total time = a + b | 683.40 | 676.90 | 680 |
| 2 | Start to load per request via bar code "START" menu then the system automatically issues related documents | | | |
| | a) Data entry time via bar code reader | 40.00 | 35.40 | |
| | b) Waiting time for program response | 118.50 | 100.80 | |
| | c) Time for printing | 428.00 | 425.30 | |
| | d) Total time = a + b + c | 586.50 | 561.50 | 570 |

Table D.2. Time Study of All Tasks in Proposed Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 3 | Do wafers inspection, records result by scanner reader | | | |
| | a) Inspection time for one wafer (1 batch = 8 wafers) | 402.20 | 427.90 | |
| | b) Inspection time for one batch | 3,217.60 | 3,423.60 | |
| | c) Time for result recording | 320.00 | 138.20 | |
| | d) Total time = b + c | 3,537.60 | 3,561.70 | 3,550 |
| 4 | Release wafers by "ACCEPT" bar code | 37.00 | 41.20 | 40 |
| 5 | Scan "START" label for Mount & Saw | 28.60 | 23.30 | 25 |
| 6 | Load the physical wafers to machine | | | |
| | a) One wafer loading time | 98.00 | 97.40 | |
| | b) Total time for one batch = (a) x 8 | 784.00 | 779.2 | 780 |
| 7 | Scan barcode i.e. worker ID, parameters | 77.50 | 74.30 | 75 |
| 8 | Start machine for running | | | |
| | a) Recall program and database of cut size | 280.00 | 396.80 | |
| | b) Run machine by cutting blade controlling with motor | 9,712.50 | 9,608.40 | |
| | c) Record quantity via key board | 155.00 | 146.40 | |
| | d) Total time = a + b + c | 10,147.50 | 10,151.60 | 10,150 |
| 9 | Scan "END" after finished process | 18.00 | 21.50 | 20 |
| 10 | Scan "START" for Die Attach process | 23.50 | 18.50 | 20 |
| 11 | Load wafers into Die Attach machine, run | | | |
| | a) Time for in-load & un-load | 987.5 | 1,012.40 | |
| | b) Epoxy dispensing/writing time | 7,086.50 | 7,103.20 | |
| | c) Pick & place die for one batch | 3,950.00 | 3,904.10 | |
| | d) Total time = a + b + c | 12,024.00 | 12,019.70 | 12,020 |
| 12 | Scan barcode i.e. worker ID, material information, machine parameters | 93.50 | 96.20 | 95 |
| 13 | Scan "END" after finished process | 27.50 | 26.90 | 27 |
| 14 | Scan "START" label for Die Attach Curing process, and load automatically cure profile | 25.10 | 23.80 | 24 |

Table D.2. Time Study of All Tasks in Proposed Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 15 | Load physical parts into oven & start curing | | | |
| | a) load and un-load time<br>b) Cure profile time<br>c) Total time = a + b | 468.50<br>132.00<br>600.50 | 502.40<br>105.00<br>607.40 | 605 |
| 16 | Scan barcode i.e. worker ID, program name, machine number | 137.60 | 140.80 | 140 |
| 17 | Scan "END" after finished process | 19.20 | 21.80 | 20 |
| 18 | Scan "START" label for Wire Bond process and load to machine | | | |
| | a) Scan barcode<br>b) Time for in-load<br>c) Total time = a + b | 29.00<br>889.40<br>918.40 | 18.20<br>895.60<br>913.80 | 915 |
| 19 | Start machine for running and visual inspect on physical parts | | | |
| | a) Bonding time<br>b) Inspection time for one batch<br>c) Total time = a + b | 14,384.20<br>6,405.00<br>20,789.20 | 14,502.10<br>6,275.30<br>20,777.40 | 20,780 |
| 20 | Scan barcode i.e. worker ID, material used, etc. and enter input-output via keyboard | 137.00 | 134.50 | 135 |
| 21 | Scan "END" after bonding finished | 33.50 | 28.90 | 30 |
| 22 | Scan "START" label at Mold process and load to machine | | | |
| | a) Scan time<br>b) Time for in-load & un-load<br>c) Total time = a + b | 26.50<br>1,744.30<br>1,770.80 | 22.10<br>1,750.30<br>1,772.40 | 1,772 |
| 23 | Start machine running | 2,837.80 | 2,841.30 | 2,840 |
| 24 | Scan barcode i.e. worker ID, material used, machine number, enter input-output via keyboard | 213.50 | 216.40 | 215 |
| 25 | Scan "END" after molding finished | 22.60 | 23.10 | 23 |
| 26 | Scan "START" label at Post Mold process, load to machine and select curing profile name | | | |
| | a) Time for scanning<br>b) Time for in-load & un-load<br>c) Select curing profile<br>d) Total time = a + b + c | 25.20<br>892.90<br>128.40<br>1,046.50 | 28.70<br>902.60<br>113.30<br>1,044.60 | 1,045 |
| 27 | Scan "END" after post mold cure finished | 24.50 | 25.20 | 25 |

Table D.2. Time Study of All Tasks in Proposed Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 28 | Scan "START" label at Laser Mark process, load to machine. | | | |
| | a) Time for scanning | 20.10 | 24.50 | |
| | b) Time for in-load & un-load | 1,012.40 | 1,005.60 | |
| | c) Time to recall device marking pattern | 304.50 | 312.40 | |
| | d) Total time = a + b + c | 1,337.00 | 1,342.50 | 1,340 |
| 29 | Scan barcode i.e. worker ID, material used, machine number, defect quantity, enter input-output via keyboard | 145.20 | 137.90 | 140 |
| 30 | Scan "END" after marking finished | 23.80 | 24.10 | 24 |
| 31 | Ship to SUBCON for solder plating | | | |
| | a) Printing packing list | 290.50 | 376.80 | |
| | b) Transportation time (round trip) | 13,313.00 | 13,072.40 | |
| | c) Plating machine cycle for one batch | 2,850.00 | 3,000.20 | |
| | d) Total time = a + b + c | 16,453.50 | 16,449.40 | 16,450 |
| 32 | SUBCON records information through run-card | 984.20 | 978.70 | 980 |
| 33 | Scan "START" label at Trim & Form process and load physical units to machine. | | | |
| | a) Time for scanning | 27.70 | 32.60 | |
| | b) Time for in-load & un-load | 907.00 | 904.20 | |
| | c) Total time = a + b | 934.70 | 936.80 | 935 |
| 34 | Scan barcode i.e. worker ID, material used, machine number, and "END" | 176.50 | 183.40 | 180 |
| 35 | Scan "START" label at Final Test process, and select testing program, equipment then load into the machine. | | | |
| | a) Time for scanning barcode | 22.30 | 26.10 | |
| | b) Time for printing run-card | 290.00 | 276.40 | |
| | c) Select test program, equipment | 165.00 | 140.50 | |
| | d) In-load time | 830.50 | 868.40 | |
| | e)Totaltime=a+b+c+d+e | 1,307.80 | 1,311.40 | 1,310 |
| 36 | Start to test and record defect quantity via keyboard and scan "END" label when process completed | 253.40 | 255.20 | 255 |
| 37 | Bake the tested parts (optional) | 20,055.00 | 20,048.00 | 20,050 |

Table D.2. Time Study of All Tasks in Proposed Manufacturing System. (Continued)

| No. | Activities | 1st measure (second) | 2nd measure (second) | Estimated Time (second) |
|---|---|---|---|---|
| 38 | Scan "START" label at QC Sampling Test process, and select testing program, equipment then load into the machine. | | | |
| | a) Time for scanning barcode<br>b) Select test program<br>c) Start testing<br>d) Total time = a + b + c | 19.00<br>216.00<br>3,162.40<br>3,397.40 | 24.60<br>347.10<br>3,022.50<br>3,394.20 | 3,395 |
| 39 | Scan "END" after QC sampling finished | 33.90 | 34.10 | 34 |
| 40 | Scan "START" label at Visual Scan process, and select product type, equipment then load into the machine. | | | |
| | a) Time for scanning, in-load, un-load<br>b) Start machine cycle for one batch<br>c) Total time = a + b | 743.00<br>8,250.00<br>8,993.00 | 886.50<br>8,102.30<br>8,988.80 | 8,990 |
| 41 | Scan "END" after scanning finished | 24.50 | 26.30 | 25 |
| | **Total time taken** | **110,726.4** | **110,734.7** | **110,729** |

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