POWER DEVICE ASSEMBLER ASSEMBLY RECIPE CONTROL THROUGH SMART MONITORING ACCESSIBLE REMOTE TOOL (SMART)

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A project report submitted in partial fulfilment of the requirements for the award of Master of Engineering (Electronics Systems)

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"POWER DEVICE ASSEMBLER ASSEMBLY RECIPE CONTROL THROUGH SMART MONITORING ACCESSIBLE REMOTE TOOL (SMART)"** was prepared by **NG PEI CHAI** has met the required standard for submission in partial fulfilment of the requirements for the award of Master of Engineering (Electronics Systems) at Universiti Tunku Abdul Rahman.

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ACKNOWLEDGEMENTS

ABSTRACT

Industrial 4.0 is where the digital technologies are integrated into physical manufacturing factories with purpose of quality control through automation and increasing the responding speed between management and machine. In terms of quality, it covers the assembly recipe control through automating the recipe upload from machine to host and download from host to machine with minimum human interference. While for responding speed, it means how fast the machine status such as utilization and alarm data can reach the management for their actions. To achieve the said objectives, integration needs to be done on machines and a host needs to be developed to carry out the task. The project scope is to be defined at the most critical process in the beginning and followed by fanning out to the remaining processes. In this case, the selected machine is power device assembler (PDA) at die attach and clip bond processes due to huge amount of recipe count, being bottleneck process with least capacity and having most critical alarms compared to other processes. A few methods that possible to be used to perform the integration, including duplicates the existing CIMT system which implemented at testing process, developing new SCADA system on the PDA machines or getting signal from the tower light of the machines. However, each of the method is having its drawbacks such as system capability to automate the recipe control as well as the utilization and alarm data accuracy obtained from the system. The final chosen method is to develop a new software named Smart Monitoring Accessible Remote Tool (SMART) and communicate through SECS/GEM protocol. With the defined method and protocol, the project is established by forming organization with related departments. Technical discussions with machine maker and vendor are carried out to understand machines capability and the required upgrade as well as the upgrade cost. Next, budget requisition and ROI calculation is carried out with management follow by infrastructure preparation and software development. Once the software development is completed by IT and machine maker, machine setup is to be arranged and carried out, follow by system UAT and deployment. Once deployment done, education is to be carried out with manufacturing members on the system usage. The project is then ended with system stability monitoring and dissolve the organization.

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LIST OF SYMBOLS / ABBREVIATIONS

SMART   Smart Monitoring Accessible Remote Tool

GDP   Gross Domestic Product

OEE   Overall Equipment Efficiency

MES   Manufacturing Execution System

CIM   Computer Integrated Manufacturing

PDA   Power Device Assembler

LGC   Laser Gate Cut

TMT   Test Mark Tape

RPN   Risk Priority Number

CIMT   Computer Integrated System Tester

PAL   Program Auto Loader

TPMS   Test Program Management System

TPRN   Test Program Release Note

SCADA   Supervisory Control And Data Acquisition

HMI   Human Machine Interface

MTU   Master Terminal Unit

RTU   Remote Terminal Unit

LabVIEW   Laboratory Virtual Instrument Engineering Workbench

PLC   Programmable Logic Controller

EAP   Equipment Automation Program

RMS   Recipe Management System

SPC   Statistical Process Control

EPM   Equipment Performance Monitoring

DAC   Data Acquisition Center

OUI   Operator User Interface

SECS   SEMI Equipment Communication Standard

GEM   Generic Equipment Model

SEMI   Semiconductor Equipment and Material International

PIC   Person In Charge

IT   Information Technology Department

IE   Industrial Engineering Department

EE   Equipment Engineering Department

PD	Purchasing Department
PP	Production Planning Department
MFG	Manufacturing Department
QA	Quality Assurance Department
WBS	Work Breakdown Structure
LAN	Local Area Network
ROI	Return of Investment
PV	Photovoltaic
MEMS	Micro Electro Mechanical System
LED	Light Emitting Diode
FPD	Flat Panel Display
PO	Purchase Order
UAT	User Acceptance Test
IP Address	Internet Protocol Address
POC	Proof of Concept
VM Server	Virtual Machine Server
kRM	Thousand Ringgit Malaysia
Mpcs	Million pieces
RM	Ringgit Malaysia
CAR	Corrective Action Request

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

The manufacturing sector is one of the most important industries to generate wealth in any nation. Currently, it is contributing 14.7% of global gross domestic product, GDP (Baenaa, et al., 2017). In Industrial 4.0 (Sung, 2018; Wagner, et al., 2017) era, digital technologies are adopted into the manufacturing industries around the globe. Industry 4.0 is a major technology revolution that will reshape the manufacturing industries as well as social and economic life (Reischauer, 2018). Cluster of European Research Projects on the Internet of Things (CERP-IoT) defines Industry 4.0 as the industrial vision that connect people and things at anytime, anyplace, with anything and anyone ideally by using any network and any service (Wagner, et al., 2017). With the penetration of Industry 4.0 in the modern manufacturing facilities, the operations are dominated with fully automated machines with lots of data such as operation yield, machine utilization and alarm data being generated for processing to optimize the manufacturing processes.

In business perspective, it includes information management toolsets such as Computer Integrated Manufacturing (CIM), Manufacturing Execution Systems (MES), and Enterprise Resource Planning (ERP) (Telukdarie, et al., 2018). The most significant technologies will be Internet of things (IoT), Internet of People (IoP), Internet of Services (IoS) (F. Zezulka, et al., 2016; Sung, 2018). The new industrial stage has changed the structure of the industry, the competition rules, and customers' demands. From the point of view of market, companies are now able to offer internet-based digital solutions to their customers with the implementation of digital technologies. With the implementation of these tools, the management of a company becomes easier and more efficient, making the company ahead of their competitors in terms of shorter setup and processing time as well as lower labour and material costs, contributing to higher productivity (Dalenogare, et al., 2018), better service and better product quality. A factory becomes easier to manage, as the resources are available through the live monitoring, the data is available with just few clicks, the financial status is available at the monitor and the decision can be easily made based on all available information (Telukdarie, et al., 2018).

With the success of the revolution, people around the globe are enjoying the benefits brought by industrialization. With the energy sources are easily available through the well-designed system, people nowadays are doing lesser in hard physical work compared to the earlier generation. Many people are participating in modern states which provide health benefits, education, and social security. They are enjoying levels of health, wealth, travel, education, and life expectancy that unimagined before the industrial revolution.

For a factory management, it brings the same concepts as those multinational companies. The material status, production status, machine status, quality performance, utilization data are needed at most efficient way for fast analysis, fast planning, fast decision making and fast action (Telukdarie, et al., 2018). With the penetration of industrial 4.0 mindset, many factories have started to transform their machines and system to achieve the said targets. For the long run, the factory is able to gain more benefits by achieving zero human dependent system, zero human error, great product quality and save cost on headcount (Arntz, et al., 2017), thanks to the automation system that developed and implemented in the factory.

Many countries in South-East Asia such as Thailand, Myanmar and Vietnam are already progressing to transform into Industry 4.0. However, Malaysia has been rather slow transforming into Industrial 4.0 as many of the factories are still holding on to the Industrial 2.0 and 2.5 systems (Ooi, et al., 2018). As the benefits of transformation into smart manufacturing could be seen only in the long run, they would rather keep the operators in doing manual work than investing in automation and IT technology. This has made Malaysia still remains at the infancy stage in terms of manufacturing technology.

Amkor Technology being among the leading companies in semiconductor industry also having its discrete devices manufacturing plant in Malaysia, after acquiring Toshiba Electronics Malaysia back in August 2013. Looking into one of the production lines which assemble diodes in Amkor Technology Malaysia, it has a few assembly processes named die attach and clip bond, where the processes are done in a module machine called Power Device Assembler (PDA). It follows by moulding, Laser Gate Cut (LGC), Honing, Plating and Test-Mark-Tape (TMT) process, as shown in Figure 1.1 (Mohd Khajazi, Control Plan of Diode Assembly Line) as below. Among these, Plating process is an outsourced process, while the remaining are in-house assembly processes.
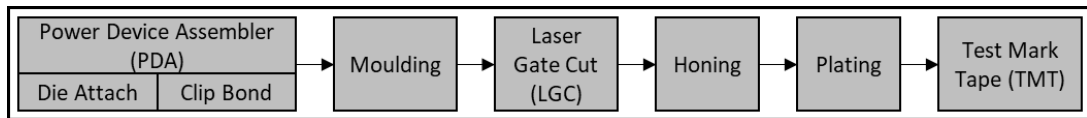
Figure 1.1 Process flow of a diode assembly line

Each process are important to assemble the diode until it ships to the customers. However, the assembly line is not yet in the optimum condition, where some of the assembly processes are rather manual, causing product quality issue and reduced productivity due to the manual job in the assembly line. Table 1.1 below shows the top manual job that handled based on the feedback by the production line members, and the possible risk severity occurrence based on the risk priority number (RPN) counted. The higher the RPN number, the higher the risk severity occurrence.

From the table, it can be concluded that manual recipe loading is having the highest RPN number due to potential of die crack if wrong recipe is loaded to the operation. The manual checking on loaded recipe is not sufficient to detect the wrong recipe loaded, where escapee is still possible to occur. Manual Overall Equipment Effectiveness (OEE) data calculation is having the second highest RPN number, where inaccurate OEE data was caused by wrong calculation or compilation on the machine stoppage time. This will give a wrong message to the management on actual machine performance, and hence possible wrong management direction. On level with manual OEE data calculation is the manual alarm data retrieval, where inaccurate alarm data was caused by data loss at machine. This will give a wrong information to the engineers on machine alarm data, where improvement might have done on less occurrence alarms.

Table 1.1 Top Manual Job and the Respective RPN Number

No	Item	Potential Failure Mode	Potential Effect	Severity (S)	Potential Cause of Failure	Occurrence (O)	Current Control	Detection (D)	RPN
1	Manual Recipe Loading	Wrong recipe loaded	Die Crack	9	Human error	5	Manual check	3	135
2	Manual OEE Data Calculation	Wrong calculation	Inaccurate data	4	Human error	5	Manual verification	5	100
3	Manual Alarm Data Retrieval	Data loss	Inaccurate data	4	Human error	5	Frequent retrieval	5	100
4	Manual Raw Material Loading	Wrong material loaded	Product failure	9	Human error	2	Material validation	3	54
5	Manual Operation Card Loading	Wrong card loaded	Product failure	9	Human error	2	Card validation	3	54
6	Manual Lot Loading/Unloading	Long cycle time	Reduce productivity	2	Manual handling procedure	5	SOP control	2	20
7	Manual Lot Track In/Out	Long cycle time	Reduce productivity	2	Manual handling procedure	5	SOP control	2	20
8	Manual Defect Quantity Track In	Long cycle time	Reduce productivity	2	Manual handling procedure	5	SOP control	2	20
9	Manual Traveler Recording	Long cycle time	Reduce productivity	2	Manual handling procedure	5	SOP control	2	20
10	Manual Preventive Maintenance Trace	Wrong traceability	Missed maintenance	3	Human error	2	Schedule verification	2	12

Among the processes, TMT process is covered by Computer Integrated Manufacturing Tester (CIMT) system (Mohd Yaki, 2017), which having Program Auto Loader (PAL) to replace the manual test program loading by operator with a test

program auto loader, as well as Test Program Management System (TPMS) to replace the manual test program approval system with a fool-proof management system. While the remaining PDA, Moulding, LGC and Honing processes, they are rather a manual management line, where the product recipes are still manually loaded by the operators. To operate a product family at these processes, the operator needs to select the correct recipe from the recipe list, loading it into the machine follow by operation at the machines.

For the machine utilization data, the machines are still monitored with an older version of monitoring format known as OEE (Amat, 2018). The OEE is very important to the management to know the performance and utilization of the machine. In this format, the operators need to record down the machine operation status in a recording sheet on whether the machine is running, stop, alarm or awaiting material. This data is then compiled once a week by the technicians and then engineers to know the OEE (Chen & Huang, 2011) result following by reporting to the management for their review.

Besides operation data, process engineers and equipment engineers are also interested in product quality and machine performance respectively (Baharain, 2018). They are usually needing to refer to machine alarm data in order to perform analysis on product quality and machine performance on particular time. To get the data, the engineers will need to attend machines and retrieve the alarm data for analysis purpose. However, the sometimes the engineers are not able to retrieve the needed data at machine due to limited storage at machine. The alarm data usually can be stored up to one week at machine, and those older data already being replaced with new data. These are considered as the obstacles to revolute into industrial 4.0, where improvements must be done to overcome the issues listed above to maintain the competitiveness of the company.

1.2 Importance of the Study

The diode assembly lines have become famous among Amkor's customers, where different kind of families were requested to be loaded into the production lines. The number of recipes in the machines especially in the PDA process has exponentially increased to cope with different kind of families to be operated at the machine. This means that the recipe list in the PDA machines has become longer, and operator has become difficult to select the correct recipe at the machine. This has caused a potential

risk of selecting wrong recipe for operation and lead to quality issues. At the same time, customers are requested to have a fool proof method to load the recipes, means the recipe must be loaded automatically for the operation. The requirements are obviously exceeded the capability of current MES system which only able to generate recipe name barcode on the lot traveller and not able to integrate until machine level. An extra effort is needed to fulfil these requirements to give the best satisfaction to the customers externally and reduce the risk of loading wrong recipe internally.

As the business expands, more families are to be loaded into the machines. This means that the production status has become tighter, and the machines must be utilized more effectively for highest output possible. Because of that, the utilization of the machines has become the target monitoring by the management as well as the production members especially in the bottleneck process, which is also the PDA process. The status of the machines such as running, stopping, having unattended alarms or having other problems needs to reach the concern managers or production line supervisors as soon as possible for effective monitoring and fast actions. To achieve this, a system linkage between the machines and a software is needed to monitor the machine utilization effectively. The system should be able to do the online monitoring of the system. With the accumulated utilization data, means it can be traced at anytime and anywhere for improvement purpose. With the developed system, the machines' utilization can be monitored effectively for optimum production output.

Machine alarm reduction is another activities that focused by the management as part of the quality and utilization improvement direction. Reducing machine alarm means reducing the possibility of producing defects, hence reducing the machine down time and improve the utilization. To retrieve the machine alarm data, a system linkage between the machines and a host is needed to collect the alarms effectively. This could ease the engineers' job to study machine alarm effectively, follow by improvement activities to reduce them to improve product quality and machine utilization.

1.3   Problem Statement

The expansion of production for more product families has yield to the increase of number of recipes, increasing its list at the machines. The operators are still using the same method to load the recipe, which they select the required recipe based on the recipe name stated on product specification card and load it manually to the machines. They are facing increasing level of difficulty to select the recipe needed, as the names

of the recipes are often similar and now increase in amount. They are having high risk of select the wrong recipe (Zhao, et al., 2016). The most severe consequences of selecting the wrong recipe is die crack (Zirilli, 2015), either crack from bottom or hairline crack on top of the die. Other possible failures from the wrong recipe selection are die chipping and solder over flow, as shown in Figure 1.2 (Musa, 2018) and Figure 1.3 (Musa, 2018) respectively. Time is wasted to find the root cause of such failures, and the process yield is dropped due to the defects. These issues would result in customer claim and possible loss of business in the long run.
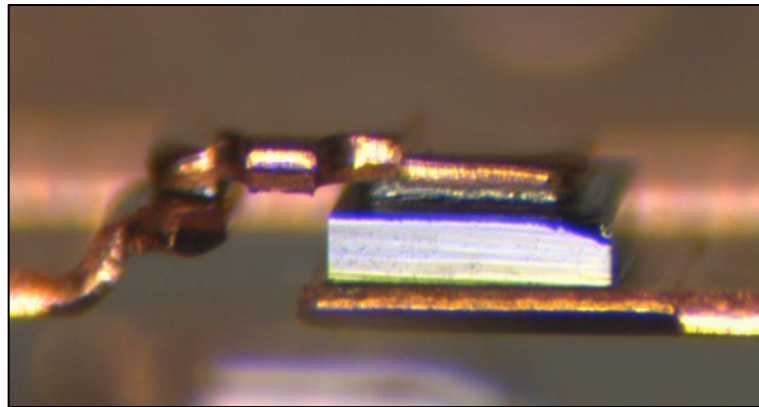
Figure 1.2 Die chipping at the diode assembly line
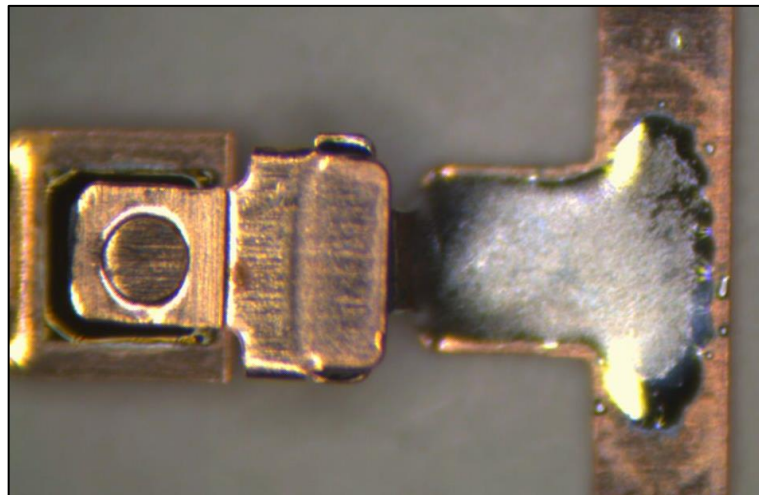
Figure 1.3 Solder over flow at the diode assembly line

Due to the increase of production demand as well, the production schedule has become tighter when time goes on. With the same number of machines, they have to produce more products at the same time. This means that the machines' performance needs to be improved to maximize their output. Therefore, machines' performance has

become the focus in the eyes of management as well as industrial engineering team to get the most output from the machines. They wish to know if the machines are underutilized or over committed, so that they can arrange the next loading. Due to these, an efficient measure and monitoring on machines' performance is needed to have correct data on it, but the current monitoring format is not the standardized format. At TMT process, it is using utilization for the monitoring, but the other processes are using Overall Equipment Efficiency (OEE) (Amat, 2018). Besides that, the current data collecting method is not efficient at all. The operators need to record the machine down time on a check sheet, and the technicians need to calculate the OEE data and compile it into report every week. The slow data source has caused an ineffective monitoring on machine OEE, while the manual calculation and recording also subject to possible wrong calculation (Zhao, et al., 2016) and caused inaccurate data.

Another constraint faced by the engineers is the machine alarm data source. Currently, the alarm data generated is stored at each individual machine. The engineers need to retrieve the alarm data manually to analyse the alarm trend and improve the planning. This has slowed down the work efficiency of the engineers especially on the alarm trend analysis. Besides that, the machines are having limited storage of alarm data at average of one-week storage, depending on the alarm occurrence rate during that week. If alarms occur more frequent on that particular week, then the new alarm data will overwrite the older data at the machine due to the limited alarm data storage.

1.4   Aims and Objectives

The aims of this work is to collects the operation data automatically to enable fast action and ease the management direction. Based on this aims, several specific objectives are outlined as below:

(i)   To develop a new software to link the current system with auto load of the operation recipe function.

(ii)   To improve the utilization monitoring effectiveness on bottleneck process by eliminating human-dependent OEE data collection.

(iii)   To improve efficiency of the alarm recording system.

1.5   Scope and Limitation of the Study

Out of many production lines, the diode assembly line was selected as the pioneer line to be transformed as it is the favourite line among customers. As shown in Figure 1.1

(Mohd Khajazi, Control Plan of Diode Assembly Line) above, the diode assembly line is having processes named PDA, Moulding, LGC, Honing, Plating and TMT. Out of these, TMT process already have CIMT to manage the test program and machine utilization. While the remaining PDA, Moulding, LGC and Honing processes are still practicing manually loaded operation. Due to that, TMT process shall be excluded from the project scope as it already has a certain level of automation system. To further narrow down the project scope, a few criteria are to be compared among the machines in the processes, namely recipe count, machine capacity and critical alarm count at each machine.

On recipe count, PDA machines are having the most at fifty recipes per machine due to having different recipes for different product families. Compared to Moulding, LGC and Honing processes, these machines are having only one recipe, as the operations are based on the product outline itself and not related with the electrical properties of each of the family.

On machine capacity, PDA machines are having the lowest capacity amongst all at 200 kpcs per day due to the complex process itself compared to Moulding, LGC and Honing processes. A PDA machine needs to attach the die piece by piece onto the frame, while the remaining are operated on frame basis. This makes PDA machine having the slowest capacity amongst all, making it the bottleneck process of total diode assembly line.

On critical alarm, PDA machines also having the most count due to the process complexity itself. Many sub-processes inside PDA machine could lead to electrical failures due to critical defects such as die crack if not managed properly. These failures could only be detected during TMT process, where it could be considered as lagging indicator as it has gone through many processes before it could be detected. Many wastes might have been produced until its detection. Comparing to other processes, most of the defects could be easily detected via inspection, hence having less waste generated compared to PDA process.

The summary of the criteria is shown in Table 1.2 (Darmarajah, 2018; Amat, 2018) as below, which can be easily concluded that the improvement project scope shall focus on PDA process first, due to having the most recipe count, least machine capacity and most critical alarm count.

Table 1.2 Diode assembly line criteria comparison

Criteria	PDA	Moulding	LGC	Honing	Remark
Recipe (count)	50	1	1	1	More recipes, more critical
Capacity (kpcs / day)	200	250	230	220	Less capacity, more critical
Critical Alarm (count)	80	20	20	40	More alarms, more critical

1.6   Contribution of the Study

The implementation of Smart Monitoring Accessible Remoting Tool (SMART) at the PDA process of diode assembly line is the first step towards smart factory transformation in Amkor Technology Malaysia. As the project leader of SMART program, I have the responsibility to ensure that the program developed is able to achieve users' requirement and ease their daily work. Therefore, I have collected users' voice as the input in design and development of the program. This includes deciding to use key number as the information to link SMART program with Manufacturing Execution System (MES) for recipe control. So as for the utilization and alarm data, I have collected users' voice in interface design and display the data in the needed format.

On the SECS/GEM communication protocol between SMART program and the machines, I've defined the main streams that needed to achieve the objectives, which are Stream 7 Process Program Management, Stream 1 Equipment Status and Stream 5 Exception (Alarm) Reporting. However, for a system to work properly, it is not sufficient to define the concern streams only. Therefore, I've defined other streams as well so that the program could work smoothly.

Cost and ROI of the project are important for the operation of the company. Therefore, with the support from Purchasing and Industrial Engineering Department, I've compiled them for budget requisition with management.

Besides making sure the technical part of the project being defined to meet the objectives of the project, I have follow up with the machine maker and vendor on the development progress as well as machine stop time and setup arrangement with Production Planning and Manufacturing Departments. This is done by organizing weekly follow up meeting with the team members. Under my management, the project was finally moved to success with the contribution from each of the team member.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To achieve recipe auto loading, auto utilization and machine alarm retrieval, it must have a server to act as active mode to request the recipe to be auto loaded into machine, request the utilization as well as alarm data from the machines at first. Then, the machines must be capable to act as passive mode to respond to recipe auto loading and send out the data accordingly. Both server and machine must be able to talk in the same language, or in other word, same protocol in order to communicate with each other. Then, a network configuration is needed either in wired mode or wireless mode to link the server with the machines complete the information transmission cycle. The server is then processing the data collected and ready to be accessed by user through a user interface. In general, the structure of the overall communication is shown in Figure 2.1 as below.
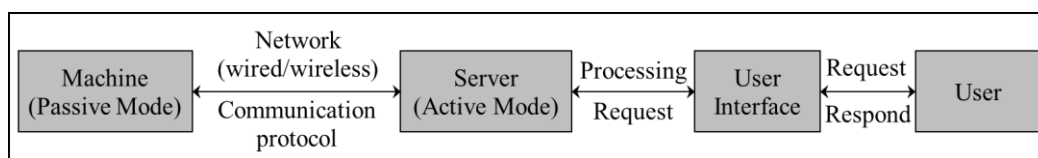
Figure 2.1 General structure of user-server-machine communication method

To achieve the said objectives, a software must be developed to perform the function. The software must have a recipe management system to handle the recipe upload from machine, letting the recipe to go through approval cycle and finally download back to the machine. The software also must capable to get machine status data such as running mode, idle mode and alarm mode. Then, the data is to be processed by the server and compiled into machine utilization data. Same goes to alarm data, the software must able to retrieve the kind of alarm data from machine whenever there is alarm at machine. Then, it must capable to process and compile the data into a useful data.

The said capabilities are to be reviewed from the current software available in the market as well as in-house software if they are able to perform the functions. Once review done, then the software is to be integrated to the PDA machine.

2.2 Literature Review

2.2.1 Computer Integrated Manufacturing Tester

Currently in Amkor Technology Malaysia, Computer Integrated Manufacturing Tester (CIMT) was deployed at the TMT Process of the diode assembly line (Mohd Yaki, 2017). CIMT offers Test Program Management System (TPMS) to manage test program, where the test program approval flow is now paperless and test programs are now stored in a centralized server to be managed by the engineers. TPMS provides fool proof system to have the test program goes through the appropriate approval flow and stores in the server. At such, it ensures the correct test program source at the server and prevents incorrect test program to be loaded to the TMT machine. Before the deployment of TPMS, the test program was managed in a manual method. The engineers need to prepare and print out Test Program Release Note (TPRN) for every test program that needs the approval flow. Once approved, then the engineers only manually copy the test program from respective computer to the server. Figure 2.2 (Mohd Yaki, 2017) below shows the comparison of initial test program management method and the TPMS system in CIMT.
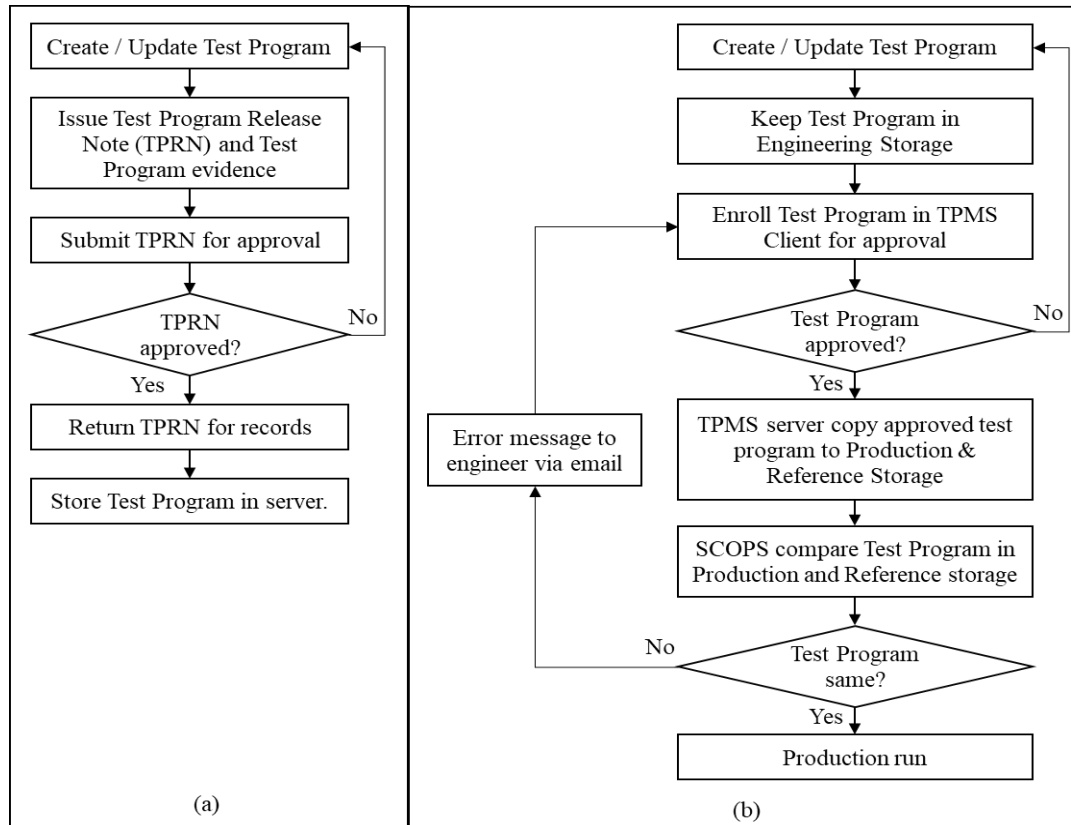
Figure 2.2 Comparison of test program management method, (a) Initial method, (b) Test Program Management System (TPMS) in CIMT

CIMT also offers Program Auto Loader (PAL) to auto load the test program to the TMT machine. By scanning the single Key Number of a product family that wants to be operated, all concern test programs that saved in the server earlier by using TPMS will now be auto loaded to the testers of TMT machine and ready for operation in just 1 minute. Refer to PAL, this test program auto loading method is a fool proof method to prevent possible wrong selection on test programs or possible skipped test program at the testers of TMT machine. Before the implementation of PAL, test program was loaded into testers of TMT machine manually by referring to the Test Card of each product family. This method is very high in risk if operator wrongly loaded the test programs or unintentionally skipped a test program. This could cause a wrong test program used or skipped test problem. Moreover, the operator takes about 5 minutes to load the test program at each single unit of tester before the whole TMT is ready for operation, which the time is wasted for operation purpose. Figure 2.3 (Mohd Yaki, 2017) below shows the comparison of initial test program loading method and the PAL system in CIMT.
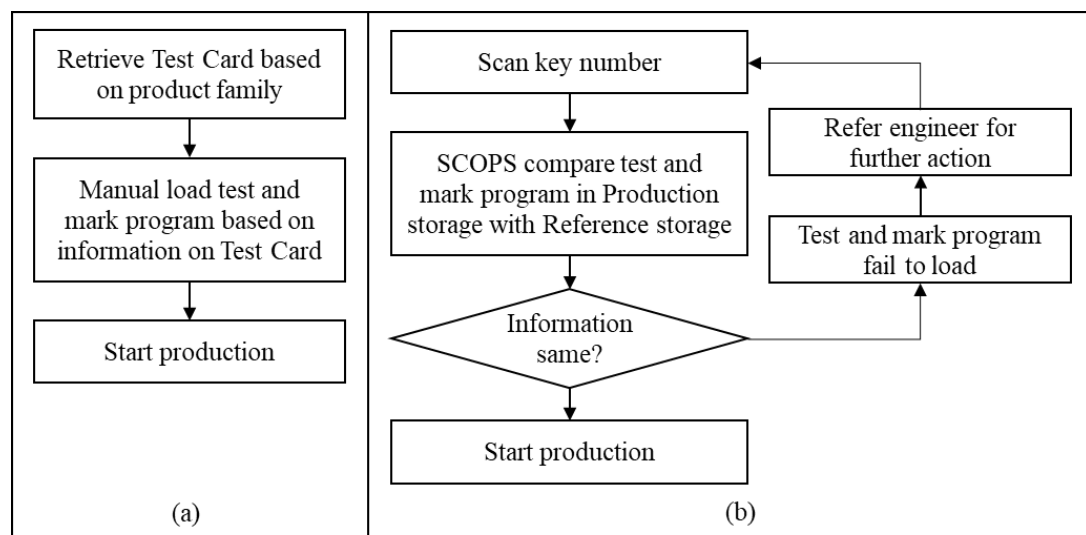
Figure 2.3 Comparison of test program loading method, (a) Initial method, (b) Program Auto Loader (PAL) system in CIMT

Besides providing test program auto loading function, PAL is able to obtain machine status and test result data since it already integrated with the TMT machine. PAL will now know whether the machine is under operation, idle or alarm, and give user the machine status live view. The machine status data is then compiled into machine utilization data, which users able to know the machine utilization status with

given time frame. For test result data, it summarizes the test result on total test pass quantity and test fail quantity for each defect bin, giving a live status of test result. This has helped the management especially the production members and process engineers to monitor the machine status and test result respectively in an effectively manner at any time. Before the implementation of CIMT, the operator was required to record down the machine status and the technician will need to compile them weekly into OEE data (Mohd Nawawi, 2016), as what they do at PDA and other machines currently. The data was slow and inaccurate due to the same problems faced at PDA process also. While the process engineer needs to depend on technician's information on test status or they will need to attend the machine to know the test status. With the implementation of CIMT, the utilization data is no more a manual job and process yield can be monitored effectively.

Due to the successful implementation at TMT machines, CIMT was considered as one of the options to be implemented at PDA machines. However, CIMT was customized to use at TMT process only and not suitable to be use at PDA machines. Firstly, TPMS was programmed to handle one product family to multiple test programs due to the requirement of one TMT machine to multiple testers structure. Compared to PDA machine, it requires only one recipe for each PDA machine only. To use TPMS, it must be re-programmed to suit the PDA requirement. Secondly, PAL is also programmed to handle multiple test programs for each TMT machine. The integration was customized together with the testers makers for PAL to function. To use PAL, integration with PDA maker is also needed for auto loader function. Thirdly, PAL also needs to be re-programmed for the test result display part, as PDA doesn't need such test result function. Although it could consider removing the function for PDA machine, yet a major change on PAL is still needed to remove them. Fourthly, CIMT doesn't offer machine alarm data for monitoring purpose. Machine alarm data is one of the major requirements in implementation, and therefore CIMT must be developed to fulfil this new function. One good thing about CIMT is its capability to handle utilization data which available in the server for access at any time needed.

In conclusion, CIMT is not suitable to be implemented at the PDA process due to the major changes needed on the program. Even if the changes are successfully done, both CIMT at TMT and PDA could not use the same interface anymore due to the major differences between these two processes. Comparing to perform the major changes, it is rather to develop a new software that suits the PDA machines.

2.2.2 MES with Machine Tower Light

Other than the in-house CIMT, another method that possible to solve the utilization data automation is by building a MES system that links with the signal from machine tower light. As most of the people know, machine tower light is functions to display machine status whether is running, idle, alarm or other status. People no need to stay beside the machine to know the machine status as they able to see the tower light display colour from some distance away to know the status. But nowadays, people not only want to see the machine status from some distance away, they also want to see that in the office, at home, or even at oversea. With computation on the signal from machine tower light, the machine status could be easily known through MES system (Low, 2005). And with further processing of data accumulated from the tower light, the utilization data could be compiled in the system and could be monitored at any time. It is another cheaper solution to get the utilization data, where less effort is needed on both system and infrastructure side.

However, from the past experience, it was found that the utilization data taken from tower light is usually higher than the actual machine output. In other word, the actual output from the machine was usually lower compared to expected output that compiled based on the utilization data obtained. After further investigation, it was found that the tower light was actually showing green when the machine is waiting for material to be fed from previous process at machine (Low, 2005). Since the machine was not consider that as a fault or error, hence the machine is not giving any alarm on that and will continue to wait for the material to be feed once finished processing the parts on it. Due to not aware by operator as well, they were not pressing stop on the machine when the machine is waiting for material. The problem had caused the utilization data to be rather inaccurate, and always higher than it supposed to be. That is yet not the most critical drawback of the system. The weakest part of it is its capability to handle recipe control and alarm data. It is obviously that the system is able to cope on utilization data only but not recipe control and alarm data due to the simple system structure that takes the machine status signal from its tower light only. There is no further integration with machine system to control the recipe as well as taking machine alarm data. Unless there is major breakthrough of this system, else the system cannot be taken into consideration as a solution on recipe control, utilization and alarm data automation.

2.2.3   Supervisory Control And Data Acquisition

Besides the systems that build in-house, there is other system available in the market, such as Supervisory Control And Data Acquisition (SCADA). SCADA systems can range from a single controller that monitors and controls a small set of processes with a single workstation for user interfacing, to large geographical systems of controllers, user interface workstations, server computers, and both local and system wide communication networks (McCrady, 2013). Nowadays, it is generally used to control a wide variety of manufacturing operations such as chemical plants, pipelines, refineries, utilities, water and transportation systems (Krutz, 2006; Rezai, et al., 2017) by collecting and controlling the data from various sensors available at the machines (Lee, et al., 2018). SCADA provides real-time operation data via a web-based solution to access the equipment and the collected data (Unde & Kurhe, 2017). It offers a more efficient control system in the operation plant at reduced operation costs. This concept is achievable as SCADA systems use a standard hardware and software communicated with improved communication protocols and linked together with outside networks. Generally, SCADA systems is made up of a few components Central Control System as the master unit, Human–Machine Interface (HMI) workstations for operation use, Programmable Logic Controllers (PLCs) at machine side, and a network communication systems that links all components together as shown in Figure 2.4 (Krutz, 2006; McCrady, 2013).
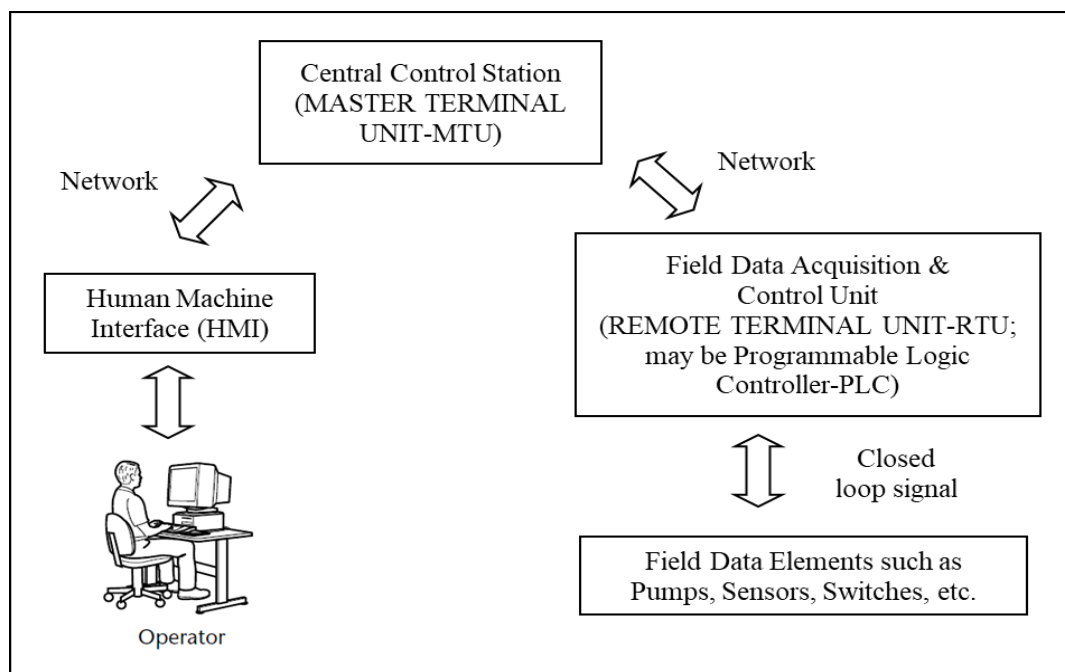

Figure 2.4 Typical SCADA system architecture

The central control system or Master Terminal Unit (MTU) is collecting operational data via sensors located at the field, processes and display the collected information at the HMI. It also provides relay control commands to either local or remote equipment (Radvanovsky & Brodsky, 2013). The complexity of the control system is vary for each plant, depends on where it is going to be use. It might be use to monitor a simple municipal water system or a complex nuclear power plant. Each controller station consists of a PLC, a RTU and other controllers that communicate with the monitoring station. These controller stations are having equipment controllers that connect directly with the operating machine or other working components of the infrastructure. The sensors take readings from the machine or the infrastructure equipment and sending data back to the controller. The MTU is then connects to the Human Machine Interface (HMI) which served as the interface for operator to control the machine or the infrastructure.

With the connection between operator and equipment through SCADA system, a real-time monitoring on the equipment status and alarm data gathering is now possible. The operators are now able to precisely analyse a huge amount of data coming from technological processes and make right decisions in the right time. This is where a real-time knowledge generation can highly improve the decision making followed by action plans in a complex industrial operations. (Skripcak & Tanuska, 2013). The realization of a virtual plant, or also called as virtual factory, was described as following: "A virtual plant is created when process simulation software, using actual or real-time data, is combined with 3-D, VR visual simulation to create a model of a specific process or facility" (Skripcak & Tanuska, 2013), are now possible with the integration of SCADA system.

Although SCADA system could bring a lot of benefits to the operation, but the system was never designed with network connectivity and security in mind (Nazir, et al., 2017; Erol-Kantarci & Mouftah, 2013). Such network integration between the machines and control systems might exposed the overall systems with cyber security risks as there are many entry points such as internet and cellular network are opened for attackers. The SCADA control systems might be more unprotected against cyber-attacks compared to other communication networks due to its real time operation characteristics (Kang, et al., 2009), as most of the SCADA communications protocols are just plain information text with no authentication messages as the gate, causing it to be easily threatened by the cyber-attack (Nazir, et al., 2017).

Due to the weaknesses, it has caused several cyber-attacks on SCADA system in the past (Cherdantseva, et al., 2016). In 2003, a computer virus called Sobig shut down a train signalling systems in Florida by spreading email attachment viruses (Miller & Rowe, 2012) No major incidents were reported due to the virus attack, except for trains delayed. In 2006, a hacker in Harrisburg, USA hacked a water treatment facility system (Guan, et al., 2011). No incident was reported due to that. On the same year also, due to overloaded traffic which caused by unspecified vulnerability in the network, resulting the system to be unresponsive and failing a number of reactor recirculation pumps of Browns Ferry nuclear plant in Alabama, USA, causing it to be manually shut down (Nicholson, et al., 2012). In the following year, an unauthorised software was installed on the SCADA system of Tehama Colusa Canal Authority by a dismissed employee on the day he was dismissed (Miller & Rowe, 2012). The damage caused was unknown due to no technical reports or analysis reported or publicized at the time. While in Natanz, Iran, the Stuxnet computer worm struck a nuclear facility in 2010, causing almost one-fifth of all centrifuges failed to operate (Miller & Rowe, 2012). Besides the examples discussed, there are many other cases were discussed by Miller and Rowe and Nicholson et al. Generally, the SCADA communications are unsecured and might exposed the operations to the threats (Rezai, et al., 2017) as per examples above.

Besides the major security threats on SCADA system, it also not able to support recipe control system. As discussed earlier, SCADA system is used mainly in data collection, system monitoring and control. It works well when dealing with such data collections and machine status live view. However, it not able to perform recipe auto loading function as per requirement of the project, as there is no system integration until the machine computer level.

To integrate SCADA system for recipe control, utilization and alarm data retrieval, the information security part of the system must be fully solved by applying counter measure such as flow whitelisting in SCADA system (Regis Barbosa, et al., 2013) to ensure the factory operation is not affected by the cyber-attack and to secure the operation information of the factory. Besides, a major program change is needed to support on recipe auto loading as per project requirement. Integration until the machine computer level is needed in order to perform recipe auto loading function. Unless the cyber-attack threats and the recipe control function being rectified, else SCADA system is definitely not a choice.

2.2.4 LabVIEW

Another software that draws attention among academic and industry is LabVIEW (Laboratory Virtual Instrument Engineering Workbench), a systems engineering software from National Instrument (NI) that enable users to visualize every aspect of the application by providing a graphical programming approach, including hardware configuration, measurement data and debugging (Chouder, et al., 2013; Ma, et al., 2011).

One of the main reasons to use LabVIEW is its common usage in both industrial and academic line (Morris & Langari, 2016). LabVIEW provides a multitude of functionalities from basic operations to advanced signal-processing components. Such capability allows it to be customized and integrated into programs of different complexity to be used in laboratory and even industrial setting. This makes LabVIEW one of the most extensive programming platform. The interface is using the dataflow model where the system is drawn or presented in a graphical method like a flowchart diagram. This is much user friendly compared to other traditional programming method that using text-written code. A simple network communication that uses common communication protocols such as RS232 and GPIB, user-friendly construction and execution interface have make it a preferred choice to construct automation simulation and execution (Hamel & Mohellebi, 2018).

Due to its user-friendly features, LabVIEW has been widely used in many industries such as monitoring in solar photovoltaic module (Rohit, et al., 2017), automatic test system (Wang, et al., 2013), simulations in laboratory (Uriča & Simonová, 2017) and validation on experimental setup (Mitra, et al., 2018). As per requirement of having real time monitoring on equipment, LabVIEW offers a solution for this. A graphical program can be developed to obtain a real time data acquisition function and then converted to utilization data (Asha, et al., 2017; Rohit, et al., 2017). However, it have drawbacks where the system is suitable only to handle those simulations or small-scale projects. It is rather too simple to handle the recipe control on the machines as well as acquiring alarm data from machines. These functions need a full integration into machine operation level, where communication in between the program and machine's computer is necessary to acquire alarm data as well as performing recipe control. With the drawbacks, LabVIEW cannot be taken into consideration in achieving recipe control, acquiring machine utilization and alarm data purpose.

2.2.5   Equipment Automation Program

Having no possibility on open-source program, a customized one could be a probably solution to achieve auto recipe loading as well as utilization and alarm data acquisition from machines. In this case, a professional private company named SEMI Integration is able to provide a customized software to achieve the above target.

SEMI Integration is an experienced company to customize a program to achieve user requirements. The system named Equipment Automation Program (EAP) performs recipe upload and download and data collections from equipment such as events and alarms data. It is then integrates with systems such as MES, RMS and SPC at the upstream based on customized requirement (John Ng, 2016). The structure of the EAP system is shown in Figure 2.5 as below.
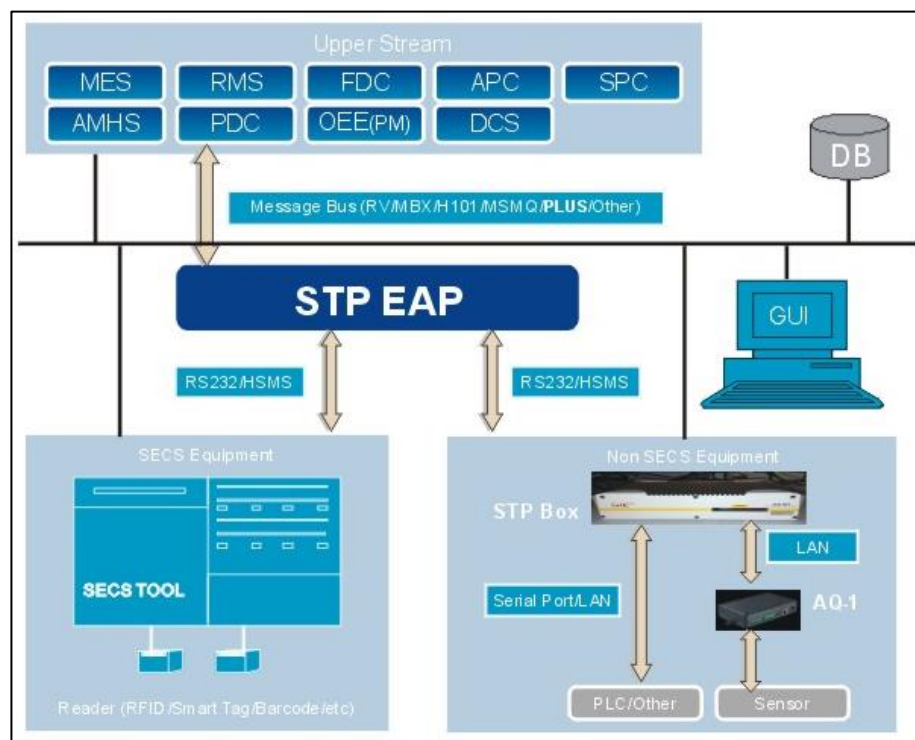
Figure 2.5 EAP System Structure from SEMI Integration

The EAP system allows shorter development and customization cycle through its well-developed core structure. It has multiple engines that can work independently or with each other for different operation purpose. It also provides a flexible platform to develop simulator to perform complex and offline testing. With the functions available in EAP system, it seems to be the perfect solution to achieve auto recipe loading and auto acquisition of machine utilization and alarm data.

As EAP system is a professional tool well provided by SEMI Integration, the software is expected to be very expensive to be implemented. At a cost near to 700 kRM, the software will definitely become a burden to the project and caused it to be over budget. Besides that, considering the software that has been customized, it would be inconvenient in the future in case of having new machines to be integrated into the system. Probably there would be extra cost if there is such requirement in the future. Therefore, EAP system would definitely not under consideration if other alternatives are available to achieve the objectives.

2.2.6   openEPM^TM_plus

Besides EAP system that provided by SEMI Integration, there are other solutions in the market to provide the similar solution as well. Another professional company named Open Integration also able to provide recipe management system and data acquisition solutions.

Similar to SEMI Integration, Open Integration provides a customized program to achieve user requirements. Different from SEMI Integration that provide all solutions within EAP system, Open Integration has their software developed separately into a few modules. Customers are able to choose the module that needed to fulfil their requirement, and Open Integration provides the solution for them. In the case of achieving auto recipe loading and utilization and alarm data acquisition, the modules needed are openRMS™_plus, DACserver™_OUI and openEPM^TM_plus (Lee, 2014).

The openRMS™_plus is designed to be easily adapted for each equipment type to perform recipe recipe uploading and downloading to avoid possible of wrong recipe loading due to human error. The structure of openRMS™_plus is shown in Figure 2.6 as below. DACserver™_OUI served as data acquisition server and operator user interface which acquire the machine alarm and operation states which being processed into utilization and alarm data. The ergonomic operator user interface serves for operator to input operation data. The structure of DACserver™_OUI is shown in Figure 2.7 as below. Finally, the openEPM^TM_plus is the user interface to display the data acquired from DACserver™_OUI in a form of reporting. The reports are displayed in a top down method to give an effective resolution for users to identify problems in the most efficient way. The structure of openEPM^TM_plus is shown in Figure 2.8 as below.
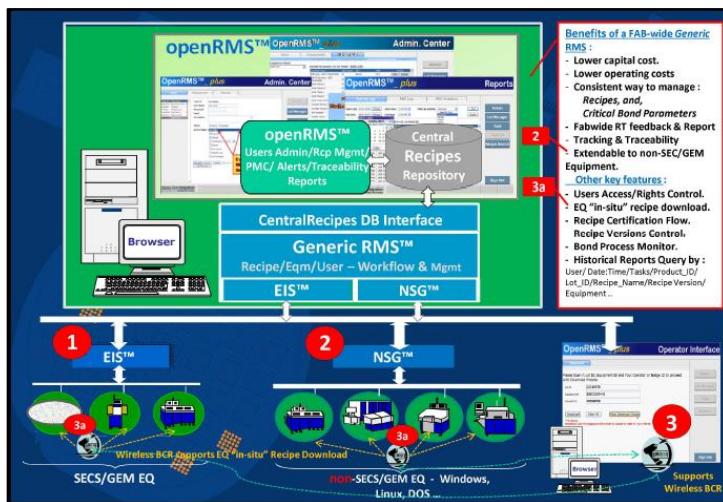
Figure 2.6 The structure of openRMS™_plus
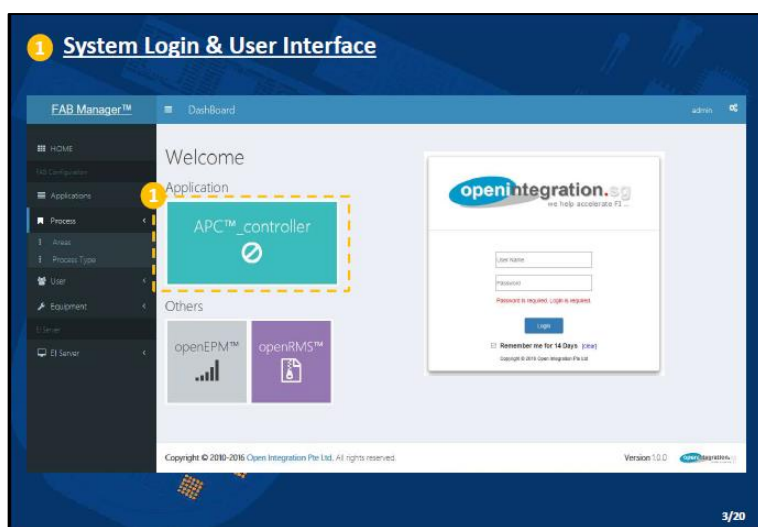
Figure 2.7 The structure of DACserver™_OUI
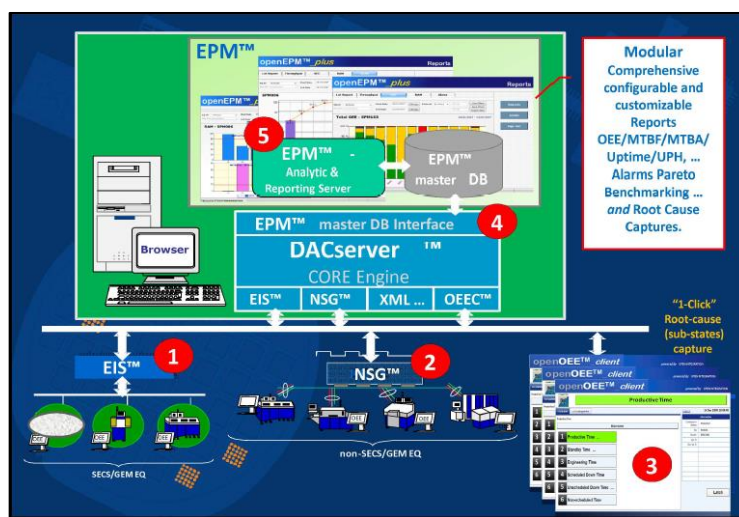
Figure 2.8 The structure of openEPM^{TM}_plus

Similar to EAP system, Open Integration's three modules provide a perfect solution to achieve the project objectives. But it also give similar problems as EAP system as well. Being customized module to achieve customer's requirement, Open Integration provides a cheaper solution at near 500 kRM, slightly cheaper compared to EAP system. However, it would still cause the project to over budget. An extra cost is also needed in the future in case of integrating new machines into the system. Therefore, Open Integration's modules would not be under consideration due to the stated reasons.

2.2.7   Summary

In general, each of the system discussed above has its own strengths and drawbacks. On in-house CIMT, TPMS and PAL have made it a great deal in terms of recipe control. It provides a rigid system on recipe approval flow follow by recipe auto loading to the machines by scanning a single key number. It also provides machine status and test result live view, which is then compiled into utilization data and test yield that needed. However, the program was designed to use at TMT process only and not suitable to be use at PDA machines, as it was designed to handle one product family to multiple test programs compared to PDA machine which require one recipe at one time only. It also not able to retrieve alarm data as per requirement. Major program changes are needed in order to fulfil the project requirements.

Another in-house program which build MES with machine tower light, it provides the cheapest solution among all, as the machine status live view and utilization data can be obtained by building a MES system that links with the signal from machine tower light. However, it is considered as the weakest system among all, as it is not able to handle both recipe control and alarm data. Besides, the utilization data is not that accurate due to signal from machine tower light can be manipulated. A major breakthrough is needed on the system in order to fulfil the project requirement.

For open source program such as SCADA, it is able to function well in terms of utilization data and machine alarm data retrieval. It allows real time monitoring the machines and creating a concept of virtual plant. However, the system was never designed with network connectivity and security in mind. It has a high security risks which open the system to cyber-attacks. It is not secure as the system might breakdown and the operation data might leak out as per few examples that discussed. Besides, it is not able to support on recipe auto loading function, as it is mainly design for data

retrieving and operation monitoring. Major program changes and upgrade are needed in order to fulfil the project requirements.

While for LabVIEW, the greatest thing of it is the capability to enable users to visualize every aspect of the application by providing a graphical programming approach. The simple user interface which cut short the development time, and it is capable of providing utilization data. However, it does not provide full integration into machine level, which it unable to communicate with machine's computer to perform recipe auto loading as well as getting alarm data. The system rather suitable to handle simulations or small-scale projects only.

A customized software by third party vendors sounds good to achieve the objective easily. EAP system from SEMI Integration and openRMS™_plus, DACserver™_OUI and openEPM^{TM}_plus from Open Integration are perfectly suits to achieve the stated objectives. They are professional and having experience in integrating the systems into company's operation has greatly reduced the risk of failure in new system development, hence ensuring the project to achieve its objectives without major problems. However, due to customized software with professional service from the vendors, the overall costs are extremely high and has raised up the project cost drastically, which caused the solution to be inconsiderable. Consider the customization was done by the vendors, it means that the future integration would be very difficult, where their involvement in the future projects are unavoidable, and causing an extra cost in the future projects. Due to such consideration, the solutions were being excluded from project execution.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1   Introduction

To overcome wrong recipe selection, manual utilization and alarm data retrieval method in Power Device Assembler (PDA) process of Diode Assembly Line, a project needs to be executed to achieve the targets. Therefore, a new program called "SMART" is to be developed to execute the tasks. SMART stands for Smart Monitoring Accessible Remote Tool, which means a smart tool that able to monitor machine status follow by getting utilization data from machine, able to access machines to perform recipe control and able to retrieve alarm data through remoting tool. The new program is expected to fulfil the auto recipe loading requirement with a single scan of key number. So as for utilization and alarm data, SMART is expected to provide the data to user with few clicks, compared to manual retrieval method previously.

For such project on diode assembly line, scope, time, budget, quality user requirements and project risk are the most complicated variant defined in the early stage for development (Chmielarz & Zborowski, 2018; Bordley, et al., 2019). For this case, the scope and user requirement of the project is very clear, where SMART program shall cater all PDA machines in Diode Assembly Line to have auto recipe loading, auto utilization data calculation and auto alarm data retrieval method. To have SMART program developed for above objectives, a cross-functional organization (Cerdeiral & Santos, 2019; Mantel Jr & Meredith, 2003) is to be formed from different departments to do the tasks as a project. This include the project scope definition and job functions (Bordley, et al., 2019) at the beginning stage. The organization is to define the work breakdown structure, SMART program architecture, core structure, as well as the risk analysis and backup plans for total project (Bjorvatn & Wald, 2018). The infrastructure for the project is to be defined at this stage.

So as for machine-server communication protocol definition, it is important to ensure both system and machines communicated with the same language. In SMART program, the communication protocol to be used is SECS/GEM protocol (SEMI Corp, 2019; Lim & Singh, 2019) which made out of defined standard stream functions to carry out tasks. It gives advantages where all kind of machines models from different makers are able to speak the same language with server. With that, it is easily to

perform recipe upload and download functions with a few defined stream functions. It also can easily collect machine's process state whether machine is running, idle or alarm, where the data is then to be compiled by SMART into utilization data. For alarm data, it able to trigger stream function to SMART and to be compiled to be alarm data later on.

Once the definitions are ready, discussion with machine maker and vendor is to be carried out and obtain quotation next. With the cost obtained, return of investment (ROI) (Cerdeiral & Santos, 2019; Matalonga & Feliu, 2012) could be calculated, and next proceed with budget requisition (Chmielarz & Zborowski, 2018) from the management.

With the budget obtained, IT programmers could perform SMART program development as per requirement to achieve the objectives. At the same time, machine SECS/GEM protocol development is to be done by machine maker and vendor once Purchase Order (PO) being issued, with upgrade on the PDA machines is to be done next to equip them with SECS/GEM capability. Once the machine upgrade done and the program is ready, user acceptance test (UAT) is to be done by all parties to confirm if the program is able to function as per requirement. Once UAT is done, the program is then to be deployed to production lines. Education is to be done next to production members on the operation procedures. And finally, the stability of SMART program is to be monitored to make sure it serves well as per its design purpose.

3.2 Project Launching

Project launching is at a very beginning of the project, where the details of the project are to be defined at this stage. This includes project scope definition, organization forming, work breakdown structure definition, SECS/GEM protocol definition, program architecture preparation, project schedule preparation, risk analysis, backup plan, machine study, infrastructure study, cost compilation and return of investment (ROI) calculation.

3.2.1 Organization Forming

To ensure the project being implemented successfully, an organization needs to be formed for project execution (Cerdeiral & Santos, 2019; Mantel Jr & Meredith, 2003). Organization is important to define roles and responsibility of each of the functional member. To achieve cost effective management, a matrix organization is to be formed

to execute the project. Matrix organization ensures short line communication among functional team to avoid possibility of communication breakdown (Mantel Jr & Meredith, 2003). The organization chart of SMART project is shown in Figure 3.1, and the roles and responsibility of each party of the organization is listed as below.

Champion

The Champion is the owner of SMART project. As the Department Manager of Information Technology (IT) Department, the Champion shall continuously advise on project execution to ensure the project achieved its target successfully.

Project Leader

The leader served as project manager of SMART project. The leader shall initiate the discussions to define the project structure, architecture and other technical items at the beginning of project. Next, the leader shall coordinate the functionality of total project to ensure the smoothness of the project as well as keeping track in terms of project progress by organizing weekly meeting with all the team members. The leader also needs to keep track on expenses so that project can be completed on time and within planned budget. The leader needs to periodically report the project progress to the Champion and follow up with each member on the overall progress. Besides, the leader shall plan the machine upgrade with Planning Department and Manufacturing Department and next arrange with machine maker and vendor on the machine setup. Also, UAT, deployment and education are to be arranged accordingly by the leader.

Information Technology (IT) Department

The main component of SMART project which stand up from Developer Team, Application Team, and Infrastructure Team. The Developer Team is formed by the developers in Amkor Technology Philippines. They shall design the total structure of SMART software and develop the software according to specification that defined. The developers shall refer CIMT software as baseline in designing SMART software and get advice from the developer in case needed. The Application Team shall work on the overall database linkage of current MES system with the SMART program that developed by Developer Team. The Infrastructure Team shall study the infrastructure readiness such as server and LAN cable, purchase and setup the required hardware at the production line.

Industrial Engineering (IE) Department

The main person in charge on production line layout. The IE engineer shall provide and advise on the layout of the PDA machines to concern members for infrastructure readiness preparation, such as network switch and LAN cable location.

Purchasing Department (PD)

The main person to initiate machine SECS/GEM protocol upgrade with machine maker and vendors. Next, the purchaser shall request machine upgrade and infrastructure quotation with the maker and vendor and negotiate on the price. The purchaser also needs to issue Purchase Order (PO) to concern maker and vendors once confirm the pricing and finally, follow up with them to ensure the required hardware, software and services are delivered on time.

Planning Department (PP)

Planning Department shall advise on production planning from time to time. The planner shall share the production plan or production forecast to the project leaders for machine upgrade planning. In case of changes in production plan, Planning Department shall update accordingly. Production status shall be monitored from time to time for machine availability for the upgrade.

Equipment Engineering (EE) Department

Equipment Engineering Department shall assist in machine upgrade based on planned schedule. Equipment Engineers shall perform the upgrade together with vendor or maker and advise on critical parts that vendor or maker shall take note during the upgrade. In case of issues, Equipment Engineers shall support on machine recovery to make sure machines are available for production at all time.

Manufacturing Department (MFG)

Manufacturing Department as main user of the system shall assist in the system UAT, together with the cooperation in arranging machine setup with project leader. Manufacturing Department shall support in confirming the system is setup according to requirement and give corrections to ensure that the SMART program that developed is fulfilling the user requirements in production line.

<u>Quality Assurance (QA) Department</u>

QA Department shall assist in system UAT to ensure that the system is functioning as per its design without affecting product quality. QA engineer need to confirm the quality of the product is fulfilling the Product Master Specification Sheet as requested prior using the system for production.
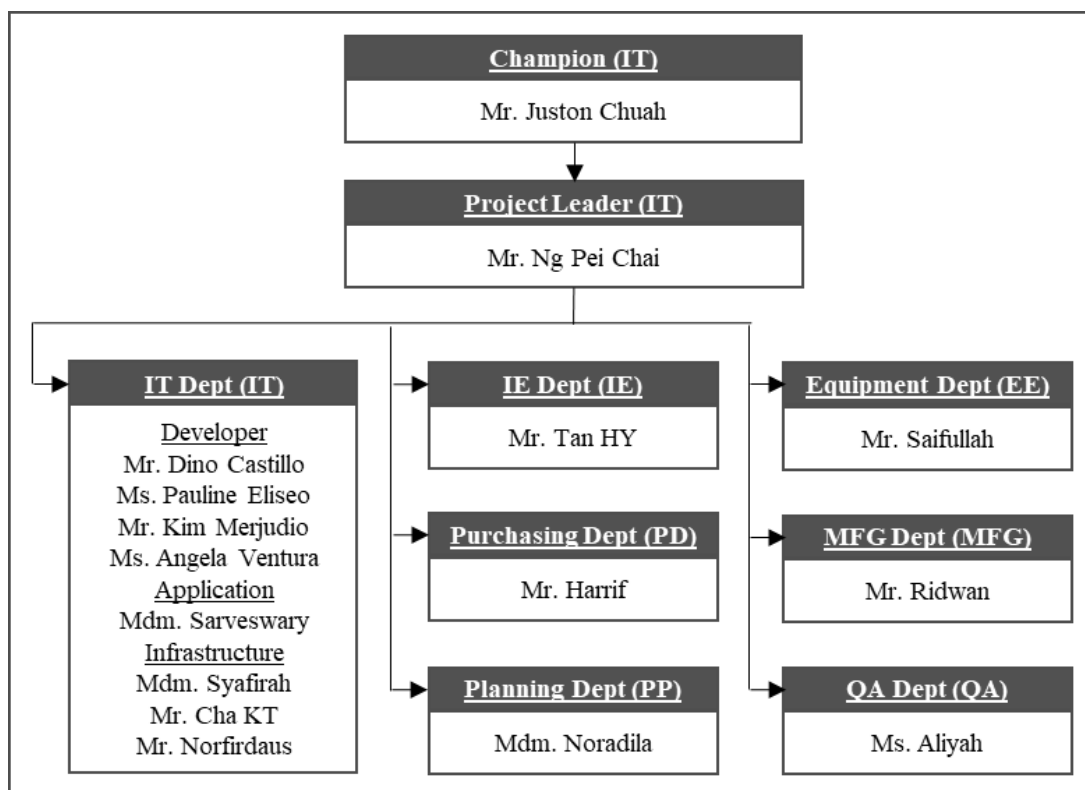
Figure 3.1 Organization Chart of SMART Project

3.2.2 Work Breakdown Structure (WBS)

Various methods are used at various stages of a project, with work breakdown structure (WBS) being among those needed at the project planning stage. By using WBS, it helps in splitting and expressing the components and products of the project into more detail parts (Sharon & Dori, 2015). An efficient WBS can prove crucial within project management planning processes when the projects being partitioned according to stages, deliverables and work packages (Irdemoosa, et al., 2015). Consequently, it can positively impact the subsequent project management processes, such as defining activities, planning project schedule, performing risk analysis and response, setup project organization, executing the project and finally monitoring the project. The WBS prepared helped in making the most output from SMART project to the PDA

process of diode assembly line. For the project leader, the partitioned stages means easier the progress follow up with each team member. The follow up will ensure the each of the task being completed as planned and ensure the project being successfully implemented at the end to achieve the objectives. A WBS is best constructed by drawing the combined experience of each of the team member or by organizing brainstorming sessions among the team members (Lester, 2017).

For SMART project, it is being partitioned into six main stages, which are project launching, development, machine setup, user acceptance test (UAT), SMART system deployment and stability monitoring. In project launching, it mainly contains the project scope definition, organization forming and job function definition as per discussed earlier. Then, it will be work breakdown structure of the total project to be discussed in this part to have the definition and implementation details of SMART project. Next, it will have SECS/GEM protocol which served as the communication protocol between machine and server later. It must be well defined to make sure the program developed is able to perform its tasks as per requirement. The architecture and SMART's core structure definition are to be constructed at this stage to have a clear big structure of the system.

Then, risk assessment (Aven, 2016; Bannerman, 2008) as a key task of project organization is to be performed to identify the possible obstacles or risks to the project which could probably dragging the project progress and the worst case, fail the project. Backup plans need to be discussed among team members and being constructed to overcome the possible obstacles.

Next, the machine list, asset number, inventory number and serial number are to be collected for the discussion with machine maker on the machine upgrade, as well as to be included in the system later on for traceability purpose. Once the list done, the machines SECS/GEM capability is to be check for the upgrade discussion next. When upgrade details done with the maker and vendor, quotation is to be requested next to know the machine upgrade cost.

At the same time, machine layout preparation is needed to know the exact location of the machines. This will be needed for infrastructure readiness study next. The infrastructure that needed for the project are computer, barcode scanner, VM server, LAN cable and network switch. Once the readiness study done, then the upgrade quotation is to be issued next to know the infrastructure cost.

With both machine upgrade cost and infrastructure cost ready, the total cost of SMART project is to be compiled next, as well as the ROI (Cerdeiral & Santos, 2019; Matalonga & Feliu, 2012) calculation. Once all the definition done, the next thing needed is to construct the Gantt Chart (Radujković & Sjekavica, 2017) for the project to allows the WBS could be follow up easily by the project leader as well as being reference for the team members. The Gantt Chart shall contains in charge department, expected start date and end date for each task. With the cost, ROI and Gantt Chart compiled, the next thing needed is to request the budget from the management in order to execute the project.

In the development stage, the PO needs to be issued to the machine maker and vendors on required items, such as machine SECS/GEM protocol upgrade and infrastructure needs. While awaiting the items to be delivered from the vendors, IT Department shall proceed with the VM server preparation. At the same time, IT developers shall proceed with the SMART core structure development, while follow up with machine maker and vendor on the SECS/GEM protocol development. LAN cable and switch installation are the next steps together with the functionality test, so as for SMART core structure testing, review debugging and stabilization of SMART core structure.

The machine setup stage will be started when the developments are done by the machine maker and vendors. In this stage, arrangements need to be done with Production Planning Department together with Manufacturing Department and Equipment Engineering Department on the machine and manpower availability for the machine upgrade. The upgrade needs to be done step by step to cover all listed machines without affecting production operation. IP address also is to be set at both machines and SMART program for communication purpose. Next, SECS/GEM communication test need to be done between machine and SMART program to ensure both sides are communicating well to carry out the tasks.

The UAT stage is another important stage to be implemented before deployment of SMART project to the production. In this stage, IT infrastructure team is required to make sure all the infrastructure are ready in the production line. This includes computer and barcode scanner that needed for SMART program. Next, the IT development and EE teams are required to perform the final system functionality test such as system's capability to perform recipe uploading and downloading well, together with utilization data and alarm data are accurately available in the system as

per requirement. Once the initial confirmation done, all parties are required to have the mutual agreement on the SMART system implementation structure and perform the system buy off together.

SMART system deployment stage is the crucial stage where SMART program is deployed to production environment for usage. The deployment means the program has been developed successfully to achieve the required objectives. After the deployment done, education needs to be done to production line members, including supervisors, process engineers, technicians and operators. The project leader shall ensure all parties are understand and able to use the system well for auto recipe control. Together with utilization data and alarm data auto capture into SMART program.

In the final monitoring stage, the project leader, IT and Manufacturing department are required to monitor the functionality of the system. Further feedback form Manufacturing is needed to perform fine tuning on the program to ensure the program bring benefits to the user as per its objectives. The summary of the WBS is shown in Appendix A.

3.2.3   SECS/GEM Protocol

SECS/GEM protocol is one of the key protocol defined by Semiconductor Equipment and Materials International (SEMI) for the benefit of the global semiconductor players, which is then expanded to other players such as photovoltaic (PV), micro-electro-mechanical system (MEMS), flat panel display (FPD) and light-emitting diode (LED) industries (SEMI Corp, 2019). SECS/GEM defines High-Speed SECS Messages Services (HSMS) in two way communication between a host and the equipment through a network cable connection regardless of operating system or programming language used. Usually, the host side is having a master controlling system provided by the factory, in this case the SMART program, and the equipment side is having a running software on the equipment computer, where in this case are the PDA machines in diode assembly line. The operating systems and the installed software of both host and equipment are independent of each other. It is common where both host and equipment are using different operating systems and the SECS/GEM software on both computers are written by factory and equipment maker respectively. This is where the standards come in value, as the factory is free to choose any operating system and not necessary to buy an interface package provided by the equipment manufacturer to communicate with the equipment (Lim & Singh, 2019).

For SMART project, SECS/GEM protocol was selected as the communication protocol due to its capability to have different kind of machine models to speak the same language with the server. Consider having various machine models in PDA process of diode assembly line, SECS/GEM protocol fulfils the requirement to cope with such various machine models. Consider having many other machine models at other processes such as Moulding and LGC, selecting SECS/GEM protocol will ease the future expansion of SMART program to these processes as well. Utilizing a standard protocol can decrease system designing costs as well as increase the reliability and productivity of the company. On an individual basis, a standard protocol helps to reduce design work, reduce communication error between host and equipment, and able to access to evolving technology and technical developments (SEMI Corp, 2019).

For recipe control, it is able to achieve through Stream 7, Process Program Management (Lim & Singh, 2019). The functions defined in Stream 7 are used to access the recipes on the equipment, transferring the recipes from equipment to the host which called as recipe uploading)or from host to the equipment which called as recipe downloading, or deleting a recipe at the equipment. A recipe is usually manipulated in a file format without the host understanding the content of the recipe, enabling it to cope with different kind recipe format of different machine models.

For utilization, the host or SMART program is unable to directly know it from the equipment. The host is usually getting the equipment event status whether is running, idle, alarm, setup or communication down. These events are defined in Stream 1, Equipment Status. The status are then to be displayed in SMART program as additional function on equipment live status. With the live status, the management or the line supervisors are able to view the equipment operation status easily, hence enable a more effective way to monitor and manage the equipment operation time. The equipment status is then computed by SMART program at the backend to become machine utilization data. The utilization data is then opened to be accessed by user via SMART Client. The computed data are daily and hourly utilization by machine base and by model base.

Next, the machine alarm data can be retrieve through Stream 5, Exception (Alarm) Reporting. Compared to an event where the equipment just need to send the state or information, GEM needs the alarm set and alarm clear signals to be reported as data collection events (Lim & Singh, 2019). Taking example where air pressure to inject solder onto die surface or frame surface is dropped below the desired level, then

an alarm might triggered on that. Once the air pressure is restored, the alarm clear condition message needs to be sent out. This is a desirable feature because the host need to use the same event and logic to record alarm conditions and data. Same as computed utilization data, some computation is done on the alarm data to display it via SMART Client also. The computed data includes alarm count by machine and alarm duration.

For a system to work properly, it is not sufficient to define the concern streams only. Some stream functions need to work in sequent in order to carry out the task correctly. For example, to download a recipe from host to equipment, it requires equipment to be in idle state. In this case, both Stream 7 and Stream 1 are needed to perform recipe download. If these two streams are not working together, downloading recipe when machine is in running mode could cause equipment computer to be corrupted, or causing wrong recipe used for the operation. Therefore, besides the three streams that needed for recipe control, utilization and alarm data retrieval, other streams also need to be defined for SMART system to work as per desired. In this case, other streams that need to be defined are Stream 2 Equipment Control and Diagnostics, Stream 6 Data Collection, Stream 9 System Error and Stream 10 Terminal Display. The desired stream functions that needed for SMART project is listed in Appendix B.

3.2.4   SMART Architecture

SMART architecture defines how the program should link from equipment to host, and next communicate with user through the client. The architecture gives the development direction to the program developer, as well as letting the infrastructure team to get ready the infrastructure accordingly.

The structure gives the idea where all equipment shall equipped with SECS/GEM communication protocol. Then, a network switch is installed in the production area to serve as central communication unit between the equipment and the VM server via LAN cable. Next, the SMART Connector served as the core processing program is to be installed in the VM server. Another SMART Client which served as the user interface is to be developed and installed in the users' computer. The SMART Client is where the user perform recipe uploading and downloading from SMART Connector to equipment. The user also shall use the client to monitor equipment live operation status, as well as retrieving utilization data and alarm data automatically from the server.

The total architecture of SMART project is shown in Figure 3.2 as below.
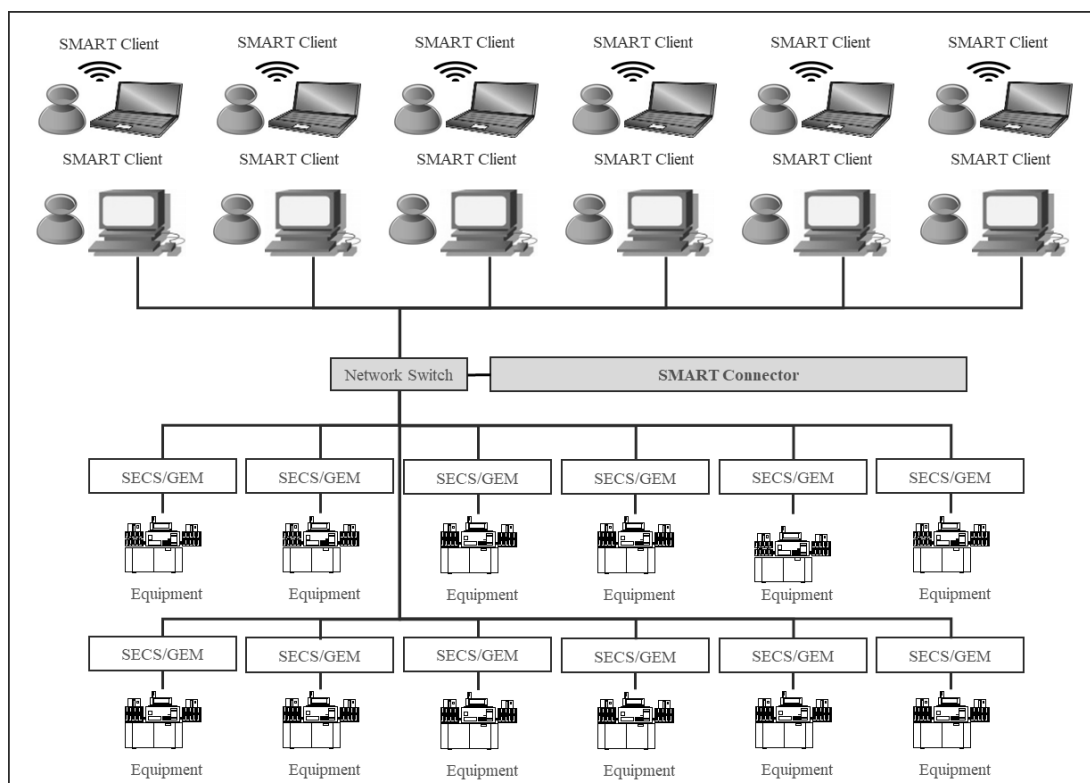
Figure 3.2 SMART Project architecture

3.2.5 SMART Core Structure Design

SMART program being automation tool needs a core structure to work at backend to carry out the tasks. Using Java as the programming platform, IT programmers tasked to build up the core structure based on the requirements from users. In order for SMART program to work out at its best, a backend processor named as SMART Connector is needed to be programmed and install in the VM server. At the front end, a user interface named as SMART Client is needed for all the interface with users on their requirements.

SMART Connector being the backend processor served as main configuration on equipment requirement. The functions needed are adding, editing and deleting the equipment that to be displayed at SMART Client. Besides, it shall have equipment list that added to the connector and serves equipment layout that to be displayed on SMART Client also. The user interface of SMART Connector is shown in Figure 3.3 as below.

Properties									Settings
Equipment List:	Add	Edit	Delete	Explore	Ping	Refresh	Equipment count		Connectivity Property
Equipment List:		Equipment Layout:							
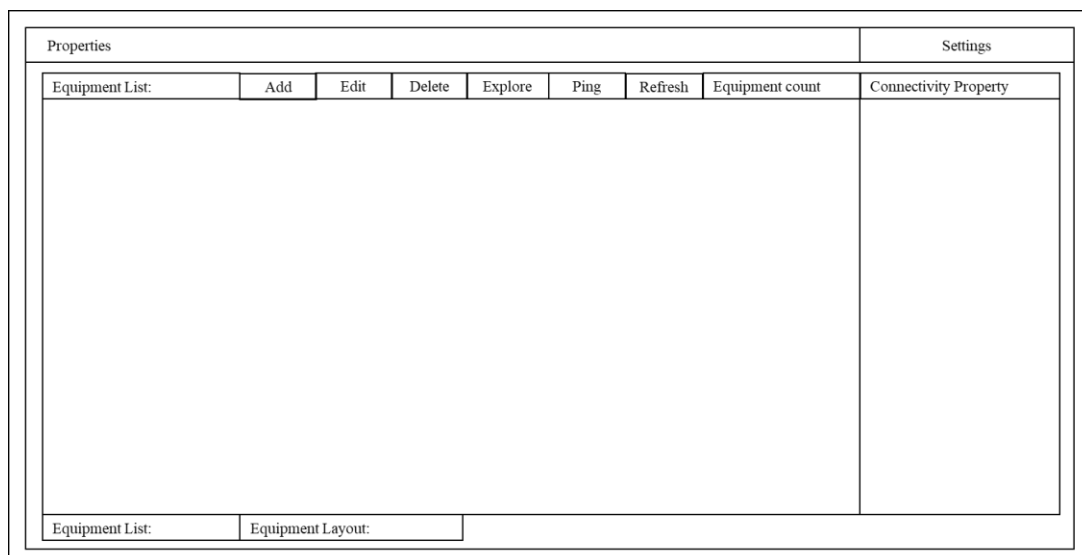
Figure 3.3 SMART Connector User Interface

For SMART Client, it plays a very important role for user to user the functions of SMART program. Therefore, the user interface needs to be user friendly and simple for user to hands on easily. Generally, it shall have three interfaces, which are the main page to display equipment status live view, recipe control page named as Program Library System for user to perform recipe operation based on key number scanning, and finally Report page for user to retrieve the utilization and alarm data.

The SMART Client main page, it displays the SMART Connector list at the left. For now, there shall have only one to display the PDA process of diode assembly line. The list shall available for future expansion on other processes. The main display will be equipment status live view at the centre of the page and the operation parameter of the selected equipment at the right of the page. This could ease the equipment operation status monitoring by the management and production supervisors. The effective monitoring could help in improving the equipment utilization and next company's revenue as whole.

On Program Library System page, it served to fulfil the first objective of the project, which is ensuring the product quality by enabling recipe auto loading to machine with single scanning of key number. Therefore, a key number scanning interface is needed following by displaying the lot information of the production lot that want to be operated. Then, it shall display the recipe information that to be uploaded or downloaded, together with the equipment information for the

corresponding recipe. An action button should be at the right most of the interface for user to proceed with the action, either to upload, qualify or download the recipe.

On Report page, it shall display the available reports for selection by users for both utilization and alarm data. Next, it shall has the date selection for the data range that needed. Then, the data shall display at the bottom of the page for user to visualize the data. The three pages of user interface are shown in Figure 3.4, 3.5 and 3.6 respectively.

Figure 3.4 SMART Client Main Page Display

Figure 3.5 SMART Client Program Library System Display

Analysis Target	Analysis Report		
	Analysis Period		Analyze
Report Information:			Save

Figure 3.6 SMART Client Report Page Display

3.2.6   Risk Analysis and Backup Plan

Almost all projects will face some obstacles and issues during its lifecycle from the concept defining until the closure stage. High failure rates of the automation projects were caused by behind schedule, without meeting requirements and completion beyond budget (Pimchangthong & Boonjing, 2017). A ''project risk'' is defined as: uncertain event or condition that if occurs has a positive or negative impact on a project's objectives (Mossalam, 2018). At such, risk management is commonly and widely adopted on project practice to ensure the project runs smoothly. The first principle of risk management according to ISO 31000 is that "risk management creates and protects value" (Willumsen, et al., 2019), as it helps to minimize the project failure rate and increase the chance to success.

For SMART project, the development stage is always the most critical part, as it involves software development from both machine maker and internal developers. The developers are running with time on SMART project quality that meets the objectives. To ensures the project is completed within the planned schedule, two developers from sister company in Philippines are invited to the site for two weeks to focus on the development job as well as performing physical checking on machines rather than using conference call to confirm that. On machine maker and vendor, an earlier deadline of 2 weeks shall be given to them to ensure the project has enough buffer time in case of delay in SECS/GEM development. Besides, close follow up from

Purchasing Department is needed to ensure they are progressing as per request. Project leader shall also plays the role in follow up the project progress by weekly basis.

To ensure the project closes with the quality that meet the objectives, machine SECS/GEM communication test and system buy off in user acceptance test stage are the key processes that testing if the machines and program developed are able to perform as per user requirements. After done the machine setup by both maker and vendor, SECS/GEM communication test must be done on model basis to ensure the machine performs as per SECS/GEM communication checklist. This shall be done together among IT developers, equipment engineer and machine maker or vendor. The next will be system buy off which shall be done by IT, EE, MFG and QA departments. In this stage, all departments shall confirm that SMART program is able to communicate with machine well and perform to meet the objectives.

Over budget is another common failure of projects, where unplanned circumstances are causing extra spending on the project. As developers from Philippines are coming to ensure the smoothness of development, hence the budget shall already including their flight, accommodation and transport. The agreement with machine maker and vendor also shall already cover all the setup and support to prevent further charge on service after sales. To prevent possible machine down and repair cost also, EE engineer shall ensure the machines are upgraded according to the procedures.

Besides the common failures as stated, other possible risks of the project includes vendor not able to develop or deliver according to project requirement, networking problems, and machines not available to upgrade due to tight production schedule. In the case where vendor is not deliver up to expectation for non-SECS/GEM machines, then an additional backup vendor is needed to support the development. It is the best to proceed with discussion with two vendors in parallel on the machine upgrade, where the better vendor will get the project, while the other one will serve as back up to the project.

Although networking is considered a very direct item that won't cause any issue, but still need to make sure that all LAN cables are setup on time and pre-confirmation need to be done to make sure the machine upgrade can be done smoothly. Support from IT department is important to confirm the setup on time and perform pre-check all the LAN cables before the upgrade. In case of LAN cable problems, a backup vendor is available to setup or change them immediately upon request despite of depending on regular vendor.

As manufacturing plant, production is always the top most priority to ensure revenue of the company. In case of tight production that affects machine's availability, support from Production Planning Department is important to monitor production status from time to time and provide alternative upgrade schedule to the Project Leader in case of any changes in production schedule. Project Leader will need to re-schedule accordingly to make sure that there is no delay in total schedule. Project Leader may arrange switching the upgrade schedule among the machines to ensure fully usage and no wastage of upgrade schedule. With the risk analysis and action plans prepared, the SMART project shall proceed smoothly without any major issues.

3.2.7 Machine Information Preparation

Machine information is prepared based on requirement of the project, where all PDA machines in diode assembly line must be capable of having recipe auto loading function, together with utilization data and alarm data auto collection. With this, the machine list is compiled based on the maker, model, asset number, inventory number and serial number. Next, the SECS/GEM capability of the machines need to be known, given that SECS/GEM capable machines are to be upgraded by the maker itself, which is Canon Machinery. While the non-SECS/GEM machines required third party vendor to upgrade the machine to SECS/GEM capable machines. In this case, SEMI Integration Sdn. Bhd. was appointed as the vendor to perform the task, due to their experience in upgrading non SECS/GEM machine and able to perform proof of concept (POC) on their product. With such, the machine list is compiled and shown in Appendix C. With the compiled data, machine upgrade discussion could be proceed with the maker and vendor, follow by upgrade quotation request from them.

At the same time, machine layout as per Figure 3.7 below is prepared to know the exact location of the machines. The layout is important for IT to prepare the infrastructure for the machines, such as LAN cables and computer location.
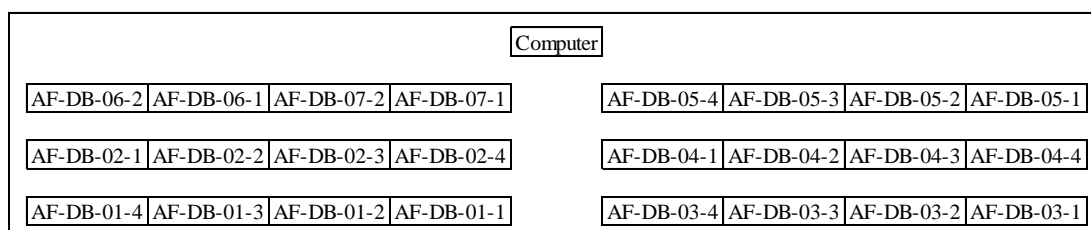
Figure 3.7 PDA Machines Layout

3.2.8   Infrastructure Readiness

With the machine layout available, the next thing to prepare is the infrastructure for SMART project. Referring to Figure 3.2 on SMART project infrastructure, one VM server is needed to install SMART Connector as the core processing for SMART program. Then, another computer is needed to install SMART Client as user interface for operator to perform recipe control. To perform recipe control by scanning the key number of a operation lot, a barcode scanner is needed at the computer to perform the scanning. To have the network connectivity for all machines and computer, a total of 25 LAN cables need to be prepared to the machine and computer location according to the layout as per Figure 3.7. Then, a switch is needed at the other end of the LAN cables to connect to the VM server. Table 3.1 below shows the specification needed for the VM server, while Table 3.2 below shows the summary of the infrastructure that needed for SMART project. With the information identified, discussion is carried out with the vendors to get the quotation for each of the item.

Table 3.1 SMART VM Server Specification

Criteria	Specification
Operation System	Windows Server 2012 R2
CPU	Intel (R) Xeon (R) E5-2665 0 @ 2.40GHz
System Type	64-bit Operating System, x64 based processor
HDD	1TB
Memory	32GB

Table 3.2 SMART Project Infrastructure Readiness

Item	Quantity
Computer	1
Barcode Scanner	1
LAN Cable	25
Switch	1

3.2.9   Cost and ROI Calculation

The cost compilation is another important part of the project, where the project leader needs the number for ROI calculation as well as budget requisition with the management. With the machine upgrade quotation from maker and vendor, the

upgrade cost can be obtained. The machine upgrade cost is where the major cost will be spent. A total number of 1,417 kRM is needed to upgrade 24 machines from 4 models. The summary of the cost is shown in Table 3.3. So as for infrastructure cost, the total cost is summarized as per Table 3.4 after negotiation with the vendor.

Table 3.3 Machine Upgrade Cost Summary

Machine Model	Quantity	Unit Price (kRM)	Total Price (kRM)
D01R	15	23	341
D310	2	20	41
CB2	4	206	823
CBM-2500	3	71	212
Total	24		1,417

Table 3.4 Infrastructure Cost Summary

Item	Quantity	Unit Price (kRM)	Total Price (kRM)
Computer	1	3.0	3.0
Barcode Scanner	1	0.3	0.3
LAN Cable	25	0.2	5.0
Switch	1	17.0	17.0
Total			25.3

In the risk analysis part, it was identified to have high risk of having no developers available at the site for SMART program development, where developers might not get the full picture of the project infrastructure through web communication. Hence, a travelling cost is needed to have the developers ready on site for the development. It is needed to prepare a round-trip flight tickets for the developers together with the accommodation for them. Transport is needed airport pick up and drop off as well as daily transport between hotel and company. The cost of preparing 2 developers support on site for 2 weeks are summarized in Table 3.5. With this, the total cost for SMART project will be 1451 kRM, as shown in the summary Table 3.6.

Table 3.5 Developers Travelling Support Cost Summary

Item	Quantity	Unit Price (kRM)	Total Price (kRM)
Flight	2	0.70	1.4
Hotel	26	0.24	6.2
Airport Transport	2	0.10	0.2
Daily Transport	10	0.05	0.5
Total			8.3

Table 3.6 SMART Project Total Cost Summary

Item	Total Price (kRM)
Machine Upgrade	1,417
Infrastructure	25.3
Developer Support	8.3
Total	1,451

To analyse the ROI of the project, first the cost of poor quality that related to wrong recipe must be known. This will be the soft saving of the project that can later being considered in ROI calculation. For past one year, there were three cases of wrong recipe cases, which caused the total compensation amount to be 730 kRM as shown in Table 3.7 as below. It is expected that no more wrong recipe selection case to happen again after the implementation of SMART program.

Table 3.7 Customer CAR Compensation Cost

Product	Customer Corrective Action Request (CAR)	Root Cause	Compensation (kRM)
S-FLAT	Die Chipping	Wrong Recipe	220
S-FLAT	Solder Over Flow	Wrong Recipe	160
M-FLAT	Die Crack	Wrong Recipe	350
Total			730

The machine utilization is expected to benefit from the implementation of SMART project also, where engineers are able to retrieve machine utilization data easily for utilization improvement project. For S-FLAT, it is expected to have additional 4.9 Mpcs capacity improvement and 1.0 Mpcs for M-FLAT from the SMART project implementation. With this, it brings a total of 197 kRM additional revenue per year from the increased capacity. The summary of the revenue from machine utilization up is shown in Table 3.8 as below.

Table 3.8 Revenue From Utilization Up

Product	Additional Capacity / Year (kpcs)	RM/pc	Gross Profit (%)	Revenue (kRM/year)
S-FLAT	4908	0.10	31%	152
M-FLAT	1044	0.12	36%	45
Total				197

Besides utilization, alarm reduction is another expected outcome from the implementation of SMART project. SMART program offers simple alarm data retrieval from equipment engineers, allowing improvement activities to be done easier with more accurate alarm data source. The improvement project would eventually improves machine utilization, hence offer extra capacity to machines with more production output. With the alarm reduction, S-FLAT and M-FLAT product are expected to give additional capacity of 1.0 Mpcs and 0.2 Mpcs respectively, with additional revenue of 31 kRM nd 9 kRM respectively. The total additional revenue will be 40 kRM per year as shown in Table 3.9.

Table 3.9 Revenue from Alarm Reduction

Product	Additional Capacity / Year (kpcs)	RM/pc	Gross Profit (%)	Revenue (kRM/year)
S-FLAT	1008	0.10	31%	31
M-FLAT	204	0.12	36%	9
Total				40

The total saving from quality up, and additional revenue from utilization up and alarm reduction will generate 967 kRM per year as shown in Table 3.10.

Table 3.10 The Saving and Revenue for SMART Project

Item	Saving /Revenue (RM/year)
Quality Up	730
Utilization Up	197
Alarm Reduction	40
Total	967

With the implementation cost of 1451 kRM and saving or revenue of 967 kRM, the ROI of SMART project can be calculated to be 1.50 year or 18 months as shown in Table 3.11. With the information, the project leader shall proceed with Gantt Chart compilation and budget requisition with management.

Table 3.11 The ROI of SMART Project

Item	Cost (kRM)	Saving (kRM)	ROI (Year)	ROI (Month)
SMART Project	1,451	967	1.50	18

3.2.10   SMART Project Gantt Chart

With the listed WBS as per Appendix A, SMART project is targeted to complete within 15 working week, commencing from 7th January as work week 1 and until 19th Apr as work week 15. The 15-week working duration was based on the time frame needed for each task and finally decided based on the critical path.

For project launching and preparation stage, it shall starts at work week 1 and complete all the required items by work week 2. The preparation stage is important to let all parties to understand the direction and work segregation of the project. Therefore it needs to be done within shortest period possible. Due to the critical program development, the development stage shall starts as soon as on work week 3 and complete at work week 10. The stage was assigned a longer period, understanding the SMART program and SECS/GEM development needs time to have a good outcome.

On machine setup stage, arrangement is crucial to ensure the setup time is not affecting routine production time. Hence, it was assigned to complete within a month time from work week 8 until work week 11. The UAT stage will takes on after development and machine setup done, starting from work week 11 to work week 12. System buy off is the most important part under UAT stage.

The deployment stage shall be on work week 13 after confirming the program is worked according to the plan. Finally, the monitoring stage shall take place on work week 14 and 15, to confirm that the program is working well in live environment. The detail Gantt Chart is shown in Appendix D.

With the Gantt Chart done, the total structure of the SMART project become crystal clear and shall proceed with budget requisition with management.

3.3   Development Stage

Development stage is the most critical stage of the project, as it determines if the final output would meet up the project objectives. In this stage, Purchasing Department shall proceed with PO issuance to the concern machine maker and vendors to start SECS/GEM development and preparation. At the same time, IT Infra Team shall prepare the VM server for SMART core structure development by the Developer team. When the LAN cable and switch are ready, workability test shall be done to confirm the connectivity between server and machine. Then, SMART core structure shall ready for testing, review and debugging stage to stabilize the whole program to function as per its design.

3.3.1   PO Issuance

After getting budget approved by the management, Purchasing Department shall proceed with PO issuance to the machine maker and vendors. This includes Canon Machinery and SEMI Integration on the machine SECS/GEM upgrade. Also, PO for infrastructure includes computer, barcode scanner, LAN cable installation and switch are to be issued to respective vendors.

To ensure the project progresses on time and able to complete within planned time frame, Purchasing Department also plays an important role to ensure all items are delivered on time. Follow up should be done from time to time to make sure maker and vendors are progressing as per plan.

3.3.2   Infrastructure Readiness

Without waiting for other preceding processes, IT Infra Team shall proceed with VM server preparation. This preparation is important for developer team to proceed with the development tasks.

The next thing needed is the LAN cable installation by the vendors. The LAN cables are needed from machine to the switch to enable the SECS/GEM communication. Switch installation is the last to complete the communication loop.

With this done, communication test and workability test is important to make sure all concern machines are able to communicate with the servers. The test ensures the smoothness of the communication next and faulty parts shall be fixed immediately.

3.3.3   SECS/GEM & SMART Development

The development stage is the most important stage to determine the successfulness of the project. In this part, machine maker and vendor need to develop the SECS/GEM requirement as per Appendix B within the time frame. Each of the stream function needs to be checked carefully to ensure the adaptability to the machine operation.

At the same time, the developer team needs to develop the core structure of the SMART program. The core structure is important to make sure it able to carry out the tasks as per requirements. The core structure includes both SMART Connector and SMART Client. Then, the team shall proceed with testing the functionality of the program from time to time, and proceed with debugging and reviewing to make SMART program more robust with its operation. This is follow by stabilization of the program to ensure its smooth operation in live environment.

3.4   Machine Setup

Machine setup stage includes the setup schedule planning with machine maker and vendor according to machines availability. Production operation is always the priority to ensure company's revenue. The machine setup could only takes place whenever the machines are not loaded with operation. Therefore, the planning is needed among Production Planning Department, Manufacturing Department, EE Department and IT Department. PP is tasked to advice on production loading from time to time and MFG to allocate machines according to the production loading. The schedule is then shared with the maker and vendor for machine setup arrangement, as well as EE and IT to perform IP address setting during the machine setup. Once setup is done, then SECS/GEM communication test needs to be carried out to ensure the machines are able to function according to the checklist.

3.4.1   SECS/GEM Setup & IP Address Setting

The first of model machine is the toughest to setup, as it involves all functionality test, troubleshooting and debugging of the program referring to the model. Therefore, a longer setup time shall be allocated to the first of model. The subsequent machines of model are then easier to setup with the first model done setup. Cooperation between PP, MFG, EE and IT Departments as well as maker and vendor is the key to arrange the setup schedule.

Once a machine setup is done, the next thing to do is to set the IP address of the machine same as those to be set in SMART Connector. IP address allows SMART Connector to identify which machine it is communicating with, and hence collecting data and performing recipe control on the identified machine. With the IP address set, the communication between host and equipment is established.

3.4.2   SECS/GEM Communication Test

SECS/GEM communication test is among the critical processes to ensure both the host and equipment are communicating well. It is where the host as active side shall send out the stream function according to the checklist and machine side as passive side to respond to the request. The communication is test not only confirming the respondent of the machine to the host, but also confirming if the host is able to send out correct stream function that understandable by machine. It is benefit to both machine maker and the IT developers to confirm the functionality of their development.

3.5   User Acceptance Test (UAT)

User Acceptance Test is part of the risk management, where it helps to assure the quality of the developed program meets the objectives of the project. As per its name, it needs all users to agree and accept the developed program on its functionality only could consider passing the test. Else, it could considered as fail if the program not achieving as per its design.

At this stage, a computer shall already installed with SMART Client and ready with barcode scanner in the production line as user interface for operator to use SMART program. Then, IT and EE shall performing pre-test or system functioning test to confirm the functionality of SMART program before calling for UAT. Finally, the system buy off can only be done with all concern parties.

3.5.1   System Buy Off

System buy off need to be done with all stakeholders so that all parties agree with the functionality of developed program. In SMART project, the stakeholders are IT, EE, MFG and QA departments, where IT as project leader needs to present on SMART's capability to upload or download recipe with a single scan of key number, together with the utilization and alarm data that obtained from machines. Then, EE, MFG and QA needs to justify the result displayed whether is fulfilling the project objectives. If all parties are agree with the result, then the UAT could considered as pass, and IT shall proceed with system deployment to production environment.

3.6   SMART System Deployment

Once UAT is passed, the next step is to deploy SMART program to the live environment and starting the usage in the PDA process of Diode Assembly Line. Along with deployment, education needs to be done to production members of all shifts, including operator, technician, supervisor, superintendent and the manager to make sure that all members know how to use the system properly.

At first, the technicians shall be educated to upload product recipe into SMART system according to key number, as the newly deployed SMART program is without any recipe within it. Next, it will be EE engineer's job to qualify if the recipe is uploaded correctly by the technician. If the recipe uploaded wrongly, EE engineer could reject the recipe back to technician to perform re-uploading. Once the recipe is qualified, then only operator could download the recipe to machine by scanning key

number of the operation lot for operation. With this, operator doesn't need to manually select the recipe from machine anymore and the objective of having recipe auto loading could be achieved.

The machine status live monitoring is the part that would benefit the management staff of the production line. The production manager, superintendent and supervisor could install SMART Client in their laptop and educated to have live view on the machine operation status whether is running, alarm or idle. This would help them in monitoring and controlling the production better.

So as for EE engineers, they shall be educated on the method to retrieve utilization data together with alarm data from SMART Client for their improvement activities. The data shall be easily available in SMART Client and therefore solving their difficulties in getting accurate data from the machines. With this, the objectives to automate the utilization and alarm data retrieval could be achieved.

3.7   Stability Monitoring

The post deployment will be stability monitoring stage. In stability monitoring stage, IT Department shall follow up the system performance with both EE and MFG Departments if it able to perform constantly stable without having issues. In the case where recipe control is not functioning well or utilization and alarm data are not accurate as per calculation or any other issues that arise, IT support on debugging is very much needed. Support from machine maker and vendor from time to time is also needed if found the problems are due to machine performance. Continuous support from IT is important to ensure users satisfaction on SMART program. The most important is to ensure the objectives project are fully achieved as per project's direction. The project shall be officially bring to close after confirming the stability performance.

3.8   Summary

SMART project that divided into six stages needs support from each of the project member in the organization to execute the tasks as per plan. Project leader plays a very important role to manage the project within the budget, as well as monitor the project progress to ensure the project smoothness and complete within planned time frame. The quality output of the project will finally give the credit to the stakeholders, as the system good performance will ensure the competitiveness of the company towards the competitors and brings revenue to the company.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1   Introduction

SMART project being executed to achieve three objectives, which are auto recipe loading, auto utilization data and alarm data retrieving from machines. The SMART Connector is developed as the backend processor with all the machine requirements and protocols are configured based on each model. While SMART Client is developed as the user interface to perform the stated objectives. After development by the maker and vendor, the machines also successfully upgraded to communicate with SECS/GEM protocol within the planned period without affecting current production quantity after fine arrangement with Production Planning and Manufacturing Departments. With the LAN cables and network switch successfully setup and linked between machines and SMART Connector, the communication between them are established to execute the jobs.

4.2   SMART Connector

SMART Connector as the central processor served as the location to configure all machines. Each machine model was developed separately as per machine's functions of each model. It was then duplicated according to the model's quantity and identified with equipment name, asset number and inventory number. Then, each of the machine was enrolled with unique IP address for system to recognize them and communicate with them individually.

There are total of fifteen machines with model D01R, four machines with model CB2, three machines with model CBM-2500 and two machines with model D310, which make up a total of twenty-four machines enrolled to the connector. Each machine was enrolled with a IP address which already specially encrypted to have communication between the machines and the connector only. This serves as part of the risk management to prevent possible virus attack from external network to the machines after the machines being connected to the network.

Figure 4.1 below shows the successfully developed SMART Connector with all the enrolled machines as per Appendix C, and Figure 4.2 shows the arrangement of the machines according to production layout.

Figure 4.1 SMART Connector
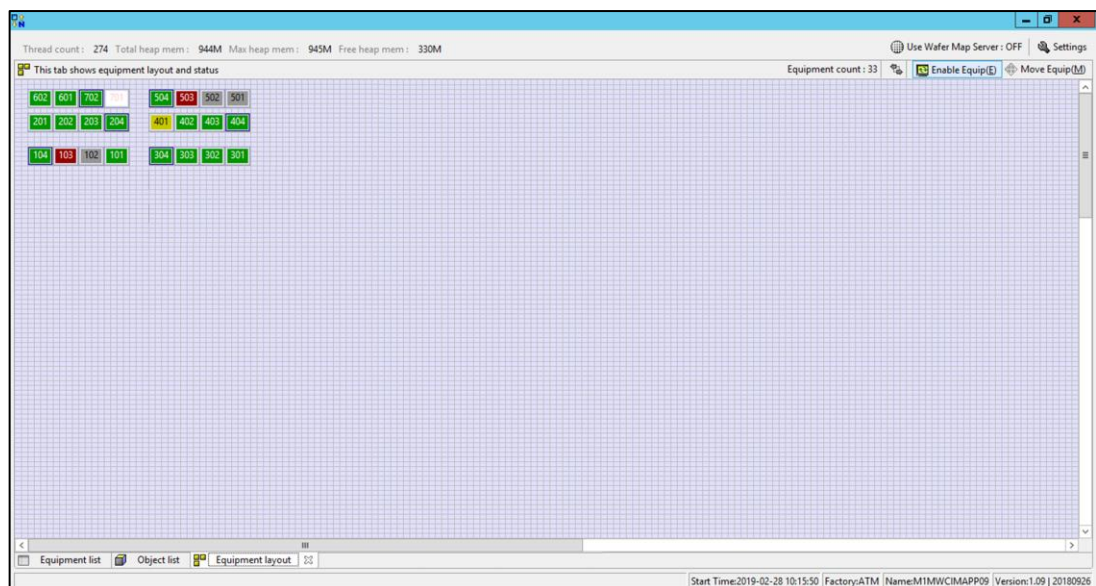
Figure 4.2 Machine Layout Setting in SMART Connector

4.3 SMART Client

SMART Client serves as the user interface between the user and the SMART system. It has the main page to display machine live operation status, either is running, idle, alarm, initialize or communication down. It ease the production members to monitor the machines and take actions immediately in case of machine not in operation. It is the extra feature offered by SMART Client to monitor the machine utilization. The machine operation status are then further processed by the SMART Connector and converts into utilization data that needed by Equipment Engineers for their usage.

SMART Client also has the SMART Connector list at the top left of the interface. The list is ready for future expansion of SMART program into other processes such as Moulding and Laser Gate Cut, or even to other production lines. At the bottom left is the summary of live machine status, where user can easily know the number of machines at stated status. At the right side is the machine operation parameter which retrieved from SECS/GEM communication with machine. Figure 4.3 shows the main page display of SMART Client.
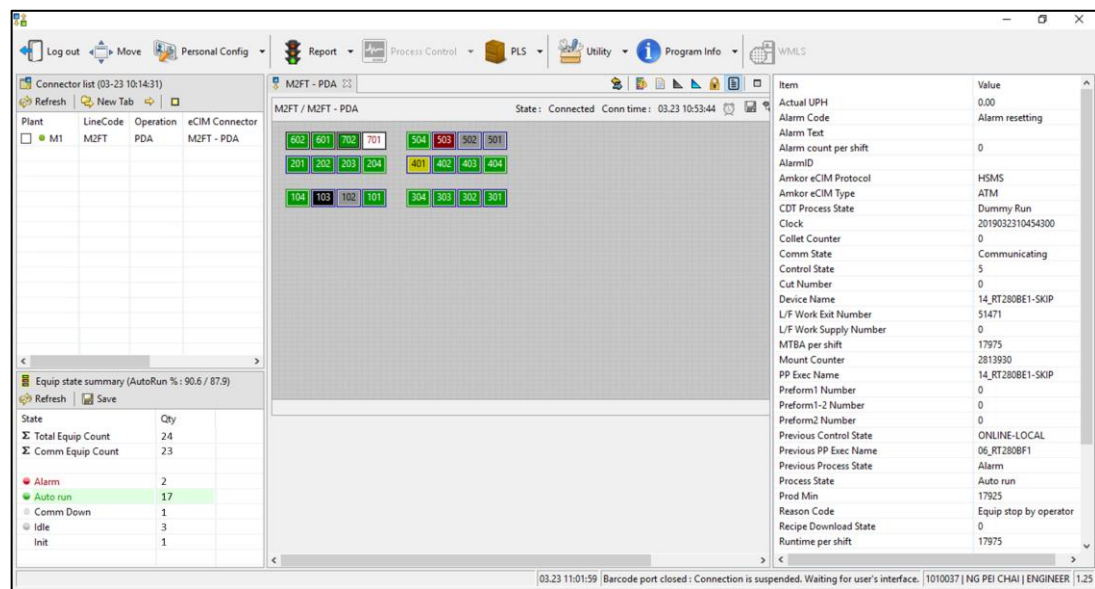
Figure 4.3 SMART Client main page display

To perform recipe auto loading function, SMART Client has Program Library System under PLS tab. By clicking the tab, it will display another window for user to perform recipe auto loading to the required machines. At this page, operator can download a recipe to the required machine by scanning the key number of the operation lot. Prior to that, technician is required to upload the correct recipe from machine to SMART Connector first. Next, the process engineer is required to qualify the recipe that uploaded by technician to confirm if correct recipe is uploaded to the connector. This is another risk management that having second person to confirm if the correct recipe is being uploaded. With the recipe stored at the connector and linked with operation lot key number, operator would just loading the recipe to the required machine by scanning the key number. At such, the risk of manually selecting wrong recipe has been gradually reduced. Figure 4.4 shows the Program Library System of SMART Client.
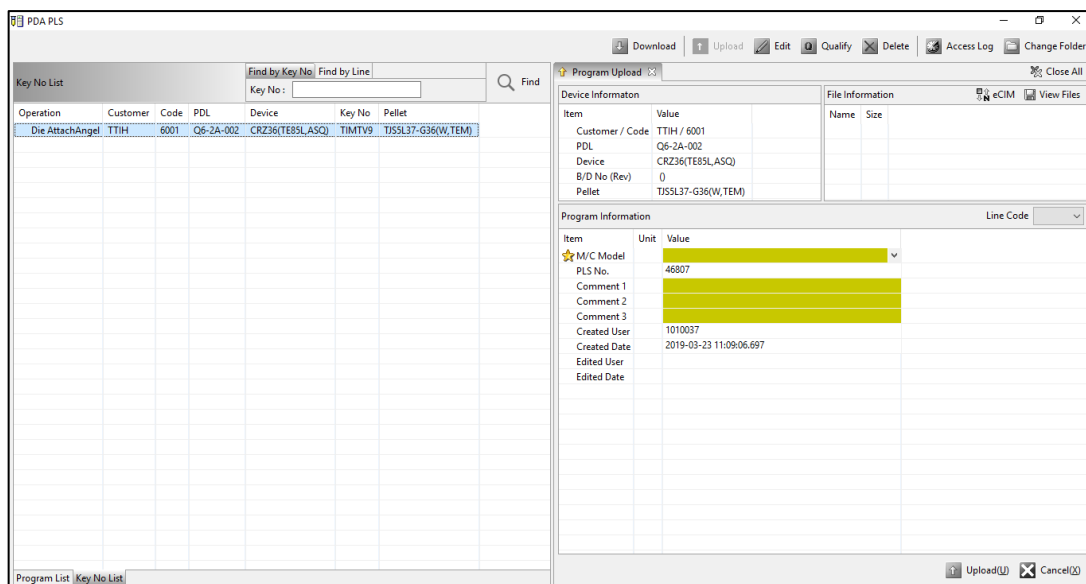
Figure 4.4 SMART Client Program Library System display

Having machine operation status being displayed live at the main page, the data is then processed by the connector to become the utilization data. The utilization data can be retrieved by the user at the Report tab of SMART Client. By clicking the report tab, another window will display for user to view the utilization data. At the top left of the window, it displays the SMART Connector list which currently display the PDA process of Diode Assembly Line, and also available for future expansion to other processes and lines. At the right side of the window, it displays the available utilization reports for selection. The user shall select the concern report follow by required analysis period, and click the Analysis button to retrieve the utilization data. The report will then display at the bottom of the page, where user can view the data directly from the window. The user can also save the data into Excel file by clicking the Save button for further analysis purpose. Figure 4.5 shows the utilization report retrieval display.

In the utilization report, it will display the utilization result of each of the machine following by running time, idle time, trouble time, initializing time and communication down time. With the result, user not only knows the machine utilization percentage, but also simple machine status time as stated, thanks to the powerful SECS/GEM protocol that able to know the machine status directly from machine's computer and send it to SMART Connector. Without further analysis, user could know further the machines' non-operation time was due to idle, alarm or other reasons, and immediate actions could be taken for improvement purpose. This function is very useful especially for production line that having high customer demand.

Similar to utilization data, the machine alarm data can be retrieved on the same display as well. The user shall select the alarm report follow by the required analysis period and click the Analysis button to retrieve the alarm data. The alarm data also can be saved into Microsoft Excel by clicking the Save button. Figure 4.6 shows the alarm report retrieval display.

The alarm report displays the alarm description of each of the machine for the selected period, and also the start time, end time and the alarm duration. With this data, the alarm type contribution can be easily known for further improvement activities.
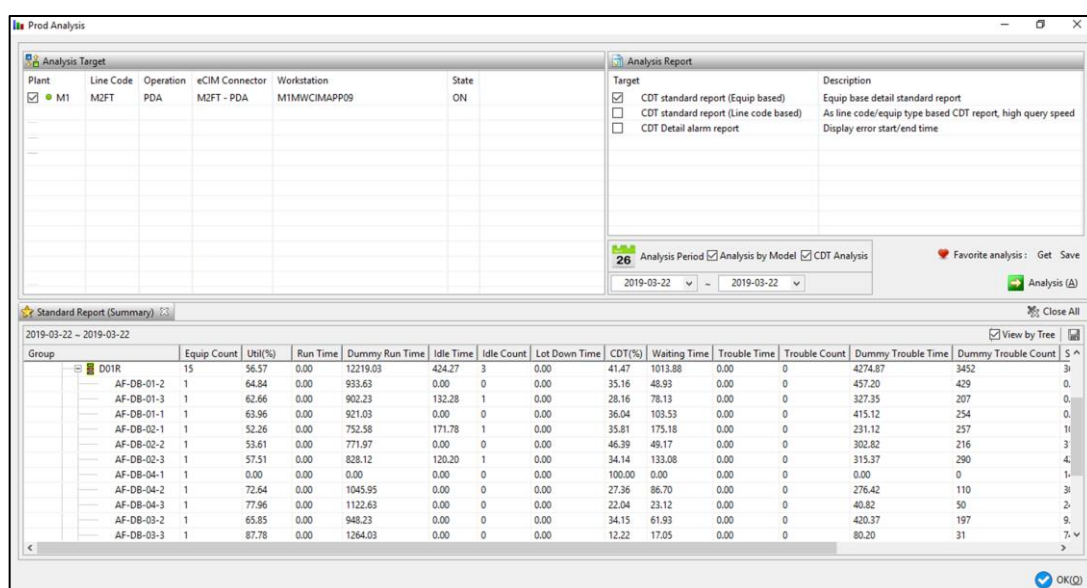
Figure 4.5 Utilization report retrieval display
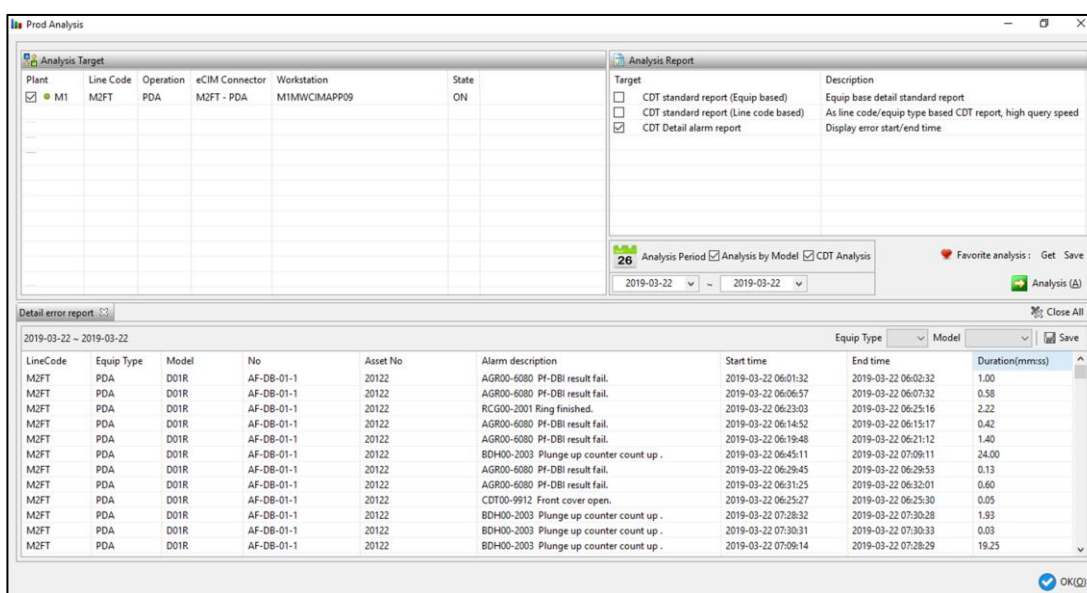
Figure 4.6 Alarm report retrieval display

4.4   Result Display

After the deployment of SMART program, education was done to all members on the procedures to use SMART Client. The main focus was to educate them on the recipe upload, qualify and download procedures. So as for engineers, they were guided on procedures to retrieve utilization and alarm data from SMART Client. The education record is shown in Appendix E

    After the education, Manufacturing members started to use SMART Client, and ten operation lots were monitored to know the recipe control functionality. This is done by uploading the recipe to SMART Connector by using SMART Client for concern operation lot, followed by recipe qualification by engineer and download back again to the PDA machine. A confirmation was done on the downloaded recipe to make sure that the correct recipe was downloaded back to the machine, and the machine is able to operate normally on the downloaded recipe. Product confirmation also done to confirm the quality of the product is not affected by the downloaded machine. The summary of the monitoring result is shown in Table 4.1 as below and the detail result is shown in Appendix F.

Table 4.1 Recipe Control Monitoring Result

No	Key No	Family	Lot No	Recipe Confirmation	Product Confirmation
1	THUZI8	STPS1L60(ER,ST,AD)	9K83500A	OK	OK
2	THUZI9	STPS2H100(ER,ST,AD)	9K83500B	OK	OK
3	THUZJ2	STPS2H100(ER,ST,AD)	9K83500B	OK	OK
4	THUZJ3	STPS2H100(ER,ST,AD)	9K83500B	OK	OK
5	THUZJ4	STPS2H100(ER,ST,AD)	9K83500C	OK	OK
6	THUZJ5	STPS2H100(ER,ST,AD)	9K83500D	OK	OK
7	THUZJ6	STTH1R02(ER,ST,AD)	9K83500E	OK	OK
8	THUZI5	STPS1L60(ER,ST,AD)	9K835009	OK	OK
9	THUZI4	STPS1L60(ER,ST,AD)	9K835009	OK	OK
10	THUZI6	STPS1L60(ER,ST,AD)	9K835009	OK	OK
Summary				10/10 OK	10/10 OK

The utilization could be downloaded to Excel file for further analysis purpose by engineers. Table 4.2 below shows the example utilization data downloaded from SMART Client which justified by the engineer.

Table 4.2 Utilization Data Downloaded from SMART Client

Group	Equip Count	Util (%)	Run Time	Dummy Run Time	Idle Time	Idle Count	Lot Down Time	CDT (%)	Waiting Time	Trouble Time	Trouble Count	Dummy Trouble Time	Dummy Trouble Count	Setup Time	Comm Down Time	Setup Count
Total Summary	24	74.64	0	34798.55	924.83	4	0	23.37	1761.8	0	0	6783.83	8073	1702.67	648.32	12
AF-DB-01-1	1	62.52	0	900.3	0	0	0	37.48	41.07	0	0	498.63	788	0	0	0
AF-DB-01-2	1	72.62	0	1045.8	0	0	0	27.38	34.53	0	0	359.67	676	0	0	0
AF-DB-01-3	1	53.35	0	768.18	0	0	0	46.65	21.58	0	0	650.22	617	0	0.02	0
AF-DB-01-4	1	94.8	0	1365.1	0	0	0	5.2	9.08	0	0	65.82	64	0	0	0
AF-DB-02-1	1	60.43	0	870.18	0	0	0	39.57	20.93	0	0	373.65	494	175.23	0	3
AF-DB-02-2	1	64.48	0	928.52	0	0	0	35.52	24.68	0	0	312.47	267	174.32	0.02	4
AF-DB-02-3	1	63.79	0	918.57	0	0	0	36.21	45.12	0	0	330.05	457	146.25	0.02	4
AF-DB-02-4	1	89.24	0	1285.03	0	0	0	10.76	52.03	0	0	102.93	151	0	0	0
AF-DB-03-1	1	63.37	0	912.52	0	0	0	36.63	8.93	0	0	460.22	575	58.33	0	0
AF-DB-03-2	1	57.8	0	832.3	0	0	0	42.2	3.45	0	0	546.65	674	57.6	0	0
AF-DB-03-3	1	89.82	0	1293.4	0	0	0	10.18	6.15	0	0	51.37	33	88.73	0.35	0
AF-DB-03-4	1	92.85	0	1336.98	0	0	0	7.15	8.02	0	0	95	90	0	0	0
AF-DB-04-1	1	42.04	0	605.32	0	0	0	57.96	21.57	0	0	381.73	427	431.38	0	0
AF-DB-04-2	1	74.65	0	1074.93	0	0	0	25.35	36.82	0	0	328.25	435	0	0	0
AF-DB-04-3	1	94.76	0	1364.57	0	0	0	5.24	21.25	0	0	54.05	82	0	0.13	0
AF-DB-04-4	1	92.52	0	1332.35	0	0	0	7.48	42.53	0	0	65.12	52	0	0	0
AF-DB-05-1	1	62.12	0	894.6	0	0	0	37.88	227.5	0	0	317.9	336	0	0	0
AF-DB-05-2	1	63.42	0	913.25	0	0	0	36.58	114.5	0	0	412.17	408	0	0.08	0
AF-DB-05-3	1	72.66	0	1046.27	0	0	0	27.34	142.33	0	0	251.38	491	0	0.02	0
AF-DB-05-4	1	85.29	0	1228.23	0	0	0	14.71	139.5	0	0	72.27	115	0	0	0
AF-DB-06-1	1	67.81	0	976.53	120.2	1	0	23.84	93.72	0	0	218.73	265	30.82	0	1
AF-DB-06-2	1	99.31	0	1430	0	0	0	0.69	0	0	0	10	1	0	0	0
AF-DB-07-1	1	59.04	0	850.17	0	0	0	40.96	10.63	0	0	39.18	49	540	0.02	0
AF-DB-07-2	1	95.3	0	1372.3	0	0	0	4.7	15.03	0	0	52.67	117	0	0	0

By using SMART Client also, the alarm data could be downloaded by engineer for machine performance analysis. Table 4.3 shows the example alarm data downloaded from SMART Client which justified by the engineer.

With the implementation of SMART program, the operators are now able to load the recipe automatically with a single scan of key number. This has ensure the product quality, as SMART ensures the diode is assembled with the correct recipe all the time. Compared to previous method, operators were required to select the recipe manually at the machine and load it for operation.

On utilization data, it is now in utilization format which standardized to TMT process, and available in the SMART Client which could be retrieved at any time needed. This has improved the data accuracy and technician work efficiency, where the data is high-accurate and doesn't need manual calculation work from the technicians. Compared to previous data in OEE format which needed operators to record machine operation time manually and compiled by the technician every week.

Table 4.3 Alarm Data Downloaded from SMART Client

LineCode	Equip Type	Model	No	Asset No	Alarm description	Start time	End time	Duration(mm:ss)
M2FT	PDA	D01R	AF-DB-01-1	20122	ULD00-2004 Work request signal off (bac	2019-03-25 06:00:16	2019-03-25 06:01:15	0.98
M2FT	PDA	D01R	AF-DB-01-1	20122	AGR00-6080 Pf-DBI result fail.	2019-03-25 06:11:34	2019-03-25 06:11:53	0.32
M2FT	PDA	D01R	AF-DB-01-1	20122	FEE00-6004 Edge detection sensor ON err	2019-03-25 06:44:49	2019-03-25 06:45:11	0.37
M2FT	PDA	D01R	AF-DB-01-1	20122	LD100-2003 Work transfer end.	2019-03-25 11:49:57	2019-03-25 11:51:08	1.18
M2FT	PDA	D01R	AF-DB-01-1	20122	LD100-6006 Loader ON/OFF switch ON.	2019-03-25 12:14:51	2019-03-25 12:14:52	0.02
M2FT	PDA	D01R	AF-DB-01-1	20122	LD100-6052 Front end operation error	2019-03-25 14:24:06	2019-03-25 14:24:24	0.3
M2FT	PDA	D01R	AF-DB-01-1	20122	WFT00-2003 Alignment error.	2019-03-25 15:51:13	2019-03-25 15:52:04	0.85
M2FT	PDA	D01R	AF-DB-01-1	20122	WFT00-6001 Outside moveable radius.	2019-03-25 23:35:13	2019-03-25 23:35:18	0.08
M2FT	PDA	D01R	AF-DB-01-1	20122	LD100-6081 Work extrusion error	2019-03-26 03:39:22	2019-03-26 03:39:50	0.47
M2FT	PDA	D01R	AF-DB-01-1	20122	RCG00-2001 Ring finished.	2019-03-26 02:57:45	2019-03-26 02:59:44	1.98
M2FT	PDA	D01R	AF-DB-01-2	20062	LD100-2001 Work finished.	2019-03-25 07:49:13	2019-03-25 07:49:18	0.08
M2FT	PDA	D01R	AF-DB-01-2	20062	LD100-6051 Front end operation not read	2019-03-25 11:36:06	2019-03-25 11:36:08	0.03
M2FT	PDA	D01R	AF-DB-01-2	20062	ILR00-6001 Island position recognition	2019-03-25 13:51:28	2019-03-25 13:52:19	0.85
M2FT	PDA	D01R	AF-DB-01-2	20062	ILR00-6071 Error and stop due to NG mar	2019-03-25 13:52:32	2019-03-25 13:52:34	0.03
M2FT	PDA	D01R	AF-DB-01-2	20062	FEE00-6015 Frame Jam Error.	2019-03-25 16:19:24	2019-03-25 16:19:29	0.08
M2FT	PDA	D01R	AF-DB-01-2	20062	PRF00-6005 Discharge plate is full.	2019-03-25 13:54:39	2019-03-25 13:54:47	0.13
M2FT	PDA	D01R	AF-DB-01-3	20063	LD100-2007 Cycle stop signal is on (bac	2019-03-25 06:28:23	2019-03-25 06:28:30	0.12
M2FT	PDA	D01R	AF-DB-01-3	20063	BDH00-6001 Chip vacuum miss error.	2019-03-25 07:47:58	2019-03-25 07:48:11	0.22
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM374 inspection3 section discontinuous NG detection anomaly	2019-03-25 06:17:36	2019-03-25 06:18:27	0.85
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM590 Unloader storage pusher drive overload (S177) anomaly	2019-03-25 09:12:12	2019-03-25 09:12:17	0.08
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM418 Mount nozzle 5 pickup ON (S114) anomaly	2019-03-25 15:07:07	2019-03-25 15:07:35	0.47
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM420 Mount nozzle 7 pickup ON (S116) anomaly	2019-03-25 15:09:49	2019-03-25 15:11:48	1.98
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM441 Mount all nozzle pickup ON anomaly	2019-03-25 15:19:32	2019-03-25 15:19:37	0.08
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM464 Connector HOOP upper limit (S148) anomaly	2019-03-25 15:00:22	2019-03-25 15:00:24	0.03
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM465 Connector HOOP lower limit (S149) anomaly	2019-03-25 14:58:21	2019-03-25 14:59:12	0.85
M2FT	PDA	CBM-2500	AF-DB-01-4	20139	ALARM518 Connector debris BOX full (S142) anomaly	2019-03-26 03:19:41	2019-03-26 03:19:49	0.13
M2FT	PDA	D01R	AF-DB-02-1	21643	AGR00-6001 Island position recognition e	2019-03-25 09:17:12	2019-03-25 09:17:22	0.17
M2FT	PDA	D01R	AF-DB-02-1	21643	CDT00-9912 Front cover open.	2019-03-25 09:15:56	2019-03-25 09:15:59	0.05
M2FT	PDA	D01R	AF-DB-02-1	21643	LD100-6074 Pusher rise operation incompl	2019-03-25 11:07:36	2019-03-25 11:07:40	0.07
M2FT	PDA	D01R	AF-DB-02-1	21643	FEE00-6205 2nd gripper frame exist.	2019-03-25 12:03:16	2019-03-25 12:03:22	0.1
M2FT	PDA	D01R	AF-DB-02-1	21643	LD100-6080 Work withdrawing error	2019-03-25 12:15:20	2019-03-25 12:16:00	0.67
M2FT	PDA	D01R	AF-DB-02-2	21644	FEE00-6136 Discharge gripper overload.	2019-03-25 06:00:35	2019-03-25 06:03:33	2.97
M2FT	PDA	D01R	AF-DB-02-2	21644	FEE00-6066 Return discharge gripper to	2019-03-25 17:06:01	2019-03-25 17:06:04	0.05
M2FT	PDA	D01R	AF-DB-02-2	21644	RCG00-6010 Chuck head take-out position	2019-03-25 18:33:30	2019-03-25 18:33:38	0.13
M2FT	PDA	D01R	AF-DB-02-3	21645	RCG00-6006 No ring on wafer table.	2019-03-25 06:47:23	2019-03-25 06:47:25	0.03
M2FT	PDA	D01R	AF-DB-02-3	21645	WFT00-6022 Expander down interlock erro	2019-03-26 05:35:16	2019-03-26 05:35:18	0.03
M2FT	PDA	CB2	AF-DB-02-4	21640	ERR.572/Pf1-2/Dispense recognition con	2019-03-25 15:10:21	2019-03-25 15:10:27	0.1
M2FT	PDA	D01R	AF-DB-03-1	21651	FEE00-6022 No work on feeder.	2019-03-25 06:50:16	2019-03-25 06:50:17	0.02
M2FT	PDA	D01R	AF-DB-03-1	21651	BDH00-6002 Chip carry back (stop up) er	2019-03-25 09:03:37	2019-03-25 09:03:39	0.03
M2FT	PDA	D01R	AF-DB-03-1	21651	LD100-6079 Pusher overload	2019-03-26 04:02:56	2019-03-26 04:03:00	0.07
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM400 Mount nozzle 3 pickup OFF (S112) anomaly	2019-03-25 07:39:51	2019-03-25 07:40:38	0.79
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM414 Mount nozzle 1 pickup ON (S110) anomaly	2019-03-25 07:38:53	2019-03-25 07:38:58	0.08
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM442 Mount collet 1 No-placement connector undetected anomaly	2019-03-25 07:36:08	2019-03-25 07:36:40	0.53
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM447 Mount collet 6 No-placement connector undetected anomaly	2019-03-25 08:06:40	2019-03-25 08:07:42	1.03
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM453 Mount collet 12 No-placement connector undetected anomaly	2019-03-25 07:49:18	2019-03-25 07:49:23	0.08
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM560 Cure-oven exit frame absent (S171) anomaly	2019-03-25 08:34:16	2019-03-25 08:34:25	0.15
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM033 Upstream-process frame-delivery-complete input signal ON anomaly	2019-03-25 11:09:09	2019-03-25 11:09:50	0.68
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM294 inspection2 section discontinuous NG detection anomaly	2019-03-25 09:54:58	2019-03-25 09:55:14	0.27
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM422 Mount nozzle 9 pickup ON (S118) anomaly	2019-03-25 12:48:54	2019-03-25 12:48:59	0.08
M2FT	PDA	CBM-2500	AF-DB-03-4	22124	ALARM443 Mount collet 2 No-placement connector undetected anomaly	2019-03-26 03:24:39	2019-03-26 03:24:43	0.07
M2FT	PDA	D01R	AF-DB-04-3	216478	BDH00-2003 Plunge up counter count up .	2019-03-26 00:32:16	2019-03-26 00:32:20	0.07
M2FT	PDA	CBM-2500	AF-DB-04-4	22123	ALARM333 dispenser3 dummy dispensing count completed board replacement anomaly	2019-03-25 16:20:45	2019-03-25 16:20:47	0.03
M2FT	PDA	CBM-2500	AF-DB-04-4	22123	ALARM011 Supply end	2019-03-25 17:52:54	2019-03-25 17:53:50	0.93
M2FT	PDA	D01R	AF-DB-05-2	22408	RCG00-6012 Front cover open.	2019-03-25 06:35:29	2019-03-25 06:35:31	0.03
M2FT	PDA	CB2	AF-DB-05-4	22100	ERR.196/Pf1/Dispense recognition acc	2019-03-25 07:56:37	2019-03-25 07:56:41	0.07
M2FT	PDA	CB2	AF-DB-05-4	22100	ERR.222/Pf2/Dispense recognition cont	2019-03-25 17:55:01	2019-03-25 17:55:05	0.07
M2FT	PDA	CB2	AF-DB-05-4	22100	ERR.743/Pf2 not origin	2019-03-26 02:36:51	2019-03-26 02:36:53	0.03
M2FT	PDA	CB2	AF-DB-05-4	22100	ERR.902/Not Home POS.	2019-03-26 02:36:51	2019-03-26 02:36:53	0.03
M2FT	PDA	D310	AF-DB-06-1	226751	FEE00-2001 Work transfer end.	2019-03-25 07:41:35	2019-03-25 07:42:31	0.93
M2FT	PDA	D310	AF-DB-06-1	226751	AGR00-6229 DBI result fail. (Area 1) (P	2019-03-25 08:45:42	2019-03-25 08:45:47	0.08
M2FT	PDA	D310	AF-DB-06-1	226751	2NDAGR00-6229 DBI result fail. (Area 1)	2019-03-25 08:57:02	2019-03-25 08:57:05	0.05
M2FT	PDA	D310	AF-DB-06-1	226751	PRF200-2003 2nd preform unit discharge	2019-03-25 10:42:44	2019-03-25 10:42:48	0.07
M2FT	PDA	D310	AF-DB-06-1	226751	2NDAGR00-6220 DBI result fail. (Area1)	2019-03-25 10:41:56	2019-03-25 10:42:40	0.73
M2FT	PDA	D310	AF-DB-06-1	226751	AGR00-6220 DBI result fail. (Area1) (Pa	2019-03-25 15:33:57	2019-03-25 15:34:52	0.92
M2FT	PDA	D310	AF-DB-06-1	226751	BDH00-6049 Plunger position interlock.	2019-03-25 15:43:54	2019-03-25 15:43:57	0.05
M2FT	PDA	D310	AF-DB-06-1	226751	FEE00-6024 Interlock due to preform uni	2019-03-25 22:53:00	2019-03-25 22:53:04	0.07
M2FT	PDA	D310	AF-DB-06-1	226751	LD100-2012?@Front machine is not AUTO.	2019-03-26 05:35:35	2019-03-26 05:35:37	0.03
M2FT	PDA	CB2	AF-DB-06-2	226752	ERR.010/Loader off (auto operation	2019-03-25 08:05:56	2019-03-25 08:06:16	0.33
M2FT	PDA	D310	AF-DB-07-1	22784	RCG00-6076 Ring chuck head overload err	2019-03-25 15:05:25	2019-03-25 15:07:19	1.9
M2FT	PDA	D310	AF-DB-07-1	22784	BDH00-2002 Collet counter count up.	2019-03-25 15:52:13	2019-03-25 15:52:56	0.72
M2FT	PDA	D310	AF-DB-07-1	22784	CDT00-9931 Front cover is open.	2019-03-25 16:04:13	2019-03-25 16:04:17	0.07
M2FT	PDA	D310	AF-DB-07-1	22784	AGR00-6080 DBI result fail.	2019-03-26 00:36:50	2019-03-26 02:36:52	0.03
M2FT	PDA	D310	AF-DB-07-1	22784	AGR00-6203 DBI result fail. (Paste NG)	2019-03-26 23:59:36	2019-03-26 23:59:47	0.18
M2FT	PDA	D310	AF-DB-07-1	22784	RCG00-2001 Ring end.	2019-03-26 05:45:29	2019-03-26 05:45:51	0.37
M2FT	PDA	D310	AF-DB-07-1	22784	FEE00-6001 Work alignment error.	2019-03-26 03:40:24	2019-03-26 03:40:33	0.15

On alarm data, it is also available to be accessed at SMART Client at any time. This has eased the work of engineers as they could retrieve the alarm data for improvement activities at any preferred time. Compared to previous practice, where engineers would need to retrieve alarm data from each machine manually with the worry of alarm data loss due to overwritten by new alarm data.

The comparison of the practice before and after SMART program implementation is shown in Table 4.4 as below.

Table 4.4 SMART Program Before-After Practice Comparison

Item	Initial Practice	Practice with SMART Program
Recipe Control	- Manual recipe selection to be loaded at machine for operation - Recipe load time: 3 mins/machine	- Auto recipe loading for operation with single scan of key number - Recipe load time: 1 min/machine
Utilization Data	- Use OEE format - Machine OEE manual record by operator and manual compiled by technician weekly - Data readiness time: 3 hrs	- Use utilization format - Machine status auto captured into Host, hence available at any time - Data readiness time: 1 min
Alarm Data	- Manual data retrieval at machine - Data readiness time: 1 hr	- Auto data captured into host - Data readiness time: 1 min

4.5   Results and Discussions

From the development output of SMART Connector and SMART Client, it is concluded that the project meets the objectives successfully. SMART Connector is working well as the central processor to perform recipe control, as well as processing the utilization data and alarm data from each individual machine. It provides an interface to perform machine configuration for communication. It also provides interface to set machine layout easily according to the actual production line, which ease the machine status monitoring according to the layout.

SMART Client is another development that beyond expectation, as it provides extra function to display machine live operating status. The machine status allows production management team to view the machine status other than in the production line, as long as the place is covered by the internet connection, therefore offers a better machine status monitoring and further actions. The function indirectly helps to improve machine operation efficiency and increase the utilization next for better production output.

The recipe auto loading with single scan of key number eliminates the risk of wrong recipe selection for operation, hence securing the product quality at the PDA process. In other word, securing product quality means reducing the defect creation

and increase the production yield, hence increase customer satisfaction to the product output. The quality assurance would attracts more customers for the product. Besides, the auto recipe loading also reduces the recipe loading time. Compared to manual recipe searching and retrieving, auto recipe loading with single scan of key number provides a faster recipe loading time. With the tight production at PDA process, the recipe loading improved efficiency also indirectly improves machine's production output.

On utilization data, SMART Client provides a user-friendly interface to view the data easily. With just a few clicks, the utilization data can be retrieved and displayed accordingly. It also designed to keep the data in the connector which allows it to be retrieved at any convenient time. Compared to previous method where utilization data was to be compiled manually by technicians every week, SMART Client provides an accurate utilization data at any time needed without worrying of possible data editing by the technicians. This allows a more effective machine utilization data monitoring by the management, as well as the production team to improve production output.

Similar to alarm data, the alarm data which retrieved from machine is well keep at SMART Connector and to be accessed by user at any convenient time by using SMART Client. Compared to previous manual alarm retrieval method where engineers need to retrieve it from each machine manually, SMART Client provides the alarm data with just a few clicks. Engineers can now retrieve the data at any time without worrying the data loss at machine due to overwritten problem. This has increased the working efficiency of the engineers with the removal of manual job.

After the deployment, the RPN number of recipe loading, utilization and alarm data source were recalculated again. It shows a drastic reduction on the RPN number on the three items. The RPN number of recipe loading is now reduced from 135 to 18, while the RPN number for both utilization data and alarm data source have been reduced from 100 to 8. This means that the risk of having wrong recipe loaded, wrong utilization data calculation and alarm data loss have been reduced gradually. This means that SMART project has been implemented successfully. The quality of the product is assured with correct recipe loaded at operation with a single scan of key number. The utilization data source is now a trusted data source eliminating the possibility of wrong calculation, and the alarm data source is now assured without data loss. The RPN number is shown in Table 4.5.

Table 4.5 RPN Number After SMART Implementation

No	Item	Potential Failure Mode	Potential Effect	Severity (S)	Potential Cause of Failure	Occurrence (O)	Current Control	Detection (D)	RPN	Action Taken	S	O	D	RPN
1	Manual Recipe Loading	Wrong recipe loaded	Die Crack	9	Human error	5	Manual check	3	135	SMART Implementation	9	1	2	18
2	Manual OEE Data Calculation	Wrong calculation	Inaccurate data	4	Human error	5	Manual verification	5	100	SMART Implementation	4	1	2	8
3	Manual Alarm Data Retrieval	Data loss	Inaccurate data	4	Human error	5	Frequent retrieval	5	100	SMART Implementation	4	1	2	8

4.6　　Summary

The SMART project was successfully developed and deployed within the planned schedule and able to achieve all project objectives. SMART Connector serves as the backend processor to manage the recipe and process both the utilization and alarm data retrieved from machines. While SMART Client serves as the user interface for them to perform recipe control such as recipe uploading and downloading by a single scan of key number, comparing to manual recipe selection at machine previously. It also allows user to retrieve both utilization data and alarm data from system, eliminating the manual data retrieval method and improve the data retrieval efficiency.

After the deployment of SMART program, education was done to all members on the procedures to perform recipe control and retrieving both utilization and alarm data. A total of 10 lots have been monitored to make sure that SMART program is able to function as per its design. This includes the recipe uploading from machine to SMART Connector by using SMART Client, followed by recipe qualification by engineer and download back again to the PDA machine. So as for both utilization and alarm data, they were downloaded to Excel file for further analysis by engineers.

With the implementation of SMART program, the recipe can be autoloaded for operation with a single scan of key number, compared to manual recipe selection and loading at machine. This has saved the recipe loading time as well as ensuring the correct recipe being used for operation. For utilization data, it is now using utilization format with the data auto captured into host, allowing engineers to retrieve it at any tome. Compared to previous OEE data that needs manual recording and compiling, the utilization data readiness is now faster at higher accuracy. So as for alarm data, auto capturing into SMART program has reduced the data readiness drastically, compared to manual retrieval method that used previously.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1   Conclusions

The support and contribution from all the functional team members has resulting the successful development and deployment of SMART project at PDA process of Diode Assembly Line. The implementation of SMART project have helped the operators to load product recipe to the machines easily with a single scan of key number. The auto recipe loading has helped in reducing the risk of wrong recipe selection at the machine, on the other hand ensuring the product quality that operated at the PDA process. With this, the first objective of the project is achieved successfully.

SMART project also having machine operation status being captured and displays it live at SMART Client, helping production members to monitor machine operation status in a more efficient way. The machine status data is then further processed by SMART Connector, resulting in machine utilization data and available for user to access it from SMART Client. The easily-accessed utilization data has replaced manual recording of OEE data by operator from time to time, manual data update by technician every shift, and manual data compilation every week. The automated utilization data also provides a more accurate data source that eliminates possibility of wrong data calculation and data manipulation, hence giving a true situation of machine utilization status for management review. With this, the second objective of the project is achieved successfully.

Similar to utilization data, SMART project also provides machine alarm data through the system integration between machines and SMART Connector. The alarms that occurred at machines will be sending to SMART Connector and further processed into alarm data. The data is then available for user at any time via SMART Client. Compared to previous manual alarm data retrieval at machine that consumed time and having risk of alarm data loss due to overwritten, SMART project makes the user more convenient at retrieving the alarm data without any data loss. With this, the third objective of the project is achieved successfully.

The implementation of SMART project is the first step for Amkor Technology Malaysia moving towards automation in manufacturing operation, ensuring the

product quality that deliver to the customers. The Industrial 4.0 mindset has slowly grows within each of the members in the company, leading the company towards automation system in the manufacturing line.

5.2   Recommendations for future work

Industrial 4.0 in an increasing trend in manufacturing industry to ensure product quality, support fast analysis, fast planning, fast decision making and hence fast action. Such environment has helped to maintain the competitiveness of the company over the competitors. The implementation of SMART project at PDA process has helped to achieve the Industrial 4.0 direction where the management, engineers and down to operators are benefit from it. However, SMART project is still having some weaknesses that need to be improve to ease the operation process. Firstly, the development of downloading multiple recipes in a module line is needed in helping production members to download the recipes easier with a single scan of key number. The development of SMART Client to display more types of utilization and alarm report is also recommended to reduce the analysis time of engineers so that the data could be used immediately from SMART Client without further analysis.

With the improvements done, it is recommended that the SMART project being implemented on all the processes of Diode Assembly Line. As TMT line already have CIMT supporting its operation and the PDA process that just implemented, hence it is recommended to expand its implementation to the remaining processes of Moulding, LGC and Honing. Such implementation could help in transforming the whole Diode Assembly Line into an automated line which compatible with Industrial 4.0 direction. To make the product more attractive, SMART project could even fan out to the outsourced Plating process. This could even help a complete quality control over the whole processes. This could ensure the product operation at the outsourced company and also product yield by performing alarm improvement activities.

As SMART project benefits the company in terms of product quality and fast analysis, therefore it is recommended to further fan out the implementation to other products in the company after implementing the whole Diode Assembly Line. The project would further transforming Amkor Technology Malaysia into a smart factory that meets Industrial 4.0 requirement and leads the Malaysia plant to be a model factory to others.

5.2.1   Project Improvement Review

Although the project achieved the objectives successfully, there were a few problems arose during the project progress. These problems were bringing risk of failing the project if not handled properly, hence must be reviewed for improvement in the future.

Firstly, the project schedule was rather tight for such scale project. The project involves two programs development, four machine models development, twenty-four machines setup, and cost near to 1,500 kRM. The project scale was rather big to be completed within fifteen weeks. The software development involvement ranging from machine maker, vendor to SMART developer. It is a high-complexity development as many parties involved in the development. For machine maker, they have advantage of understanding the machine made by them, yet developing three models in a four-week timeline is rather challenging for them. For third-party vendor, time is needed to study the machine structure follow by designing the upgrade for the machine. So as for IT developers who needs to develop both SMART Connector and Client within a six weeks' time.

Besides the development time, the three-week setup time was also rather tight for total of twenty four machines, especially when the production schedule is also tight with customer demand. This means an average of 8 machines setup per week, which needs to be arranged carefully among production members, equipment engineer, machine maker and the vendor. It allows no space of failure for setup, else it might cause the production shortage or the total project schedule to be delayed.

Knowing development and setup are critical processes that need longer time, the project definition time was pull to within two weeks to buy some time for them. However, project definition time is also an important process, as it defines the whole structure of the project. A wrong definition might leads the project to wrong direction, causing a waste of money and effort of all team members.

Due to the complexity of the project and the risks stated above, therefore it is recommended to start the project in smaller scale, such as involving one model development only as the pioneer of the project follow by fanning out to other models. It can also starts the project in other processes that having less machine or model count such as LGC process. With this, it is gradually reduce the project failure risk due to the experience gained from a smaller-scale project.

On the other hand, the project involved travelling support of developers from sister plant at Philippines. The arrangement was done so to ensure the project is completed on time. Such arrangement can be avoided if the project was planning with longer schedule, which make the remote development a possible one. At such, a total of 8.3 kRM travelling support cost could be saved if the developers give a remote support from Philippines.

Besides that, the program development should able to start as early as week 3 rather than week 4 while Purchasing Department proceeds with PO issuance, as the developers are actually no need to wait for the PO issuance to start their work. Such arrangement shall allow the developers to have extra one week for SMART program development, increasing from six weeks to seven weeks.

5.2.2   Project Improvement Proposal

The SMART project able to achieve all its objectives and complete within schedule was a great achievement due to the effort from all team members. However, it could become better if there are improvement in a few points. The improvements could help the users to benefit even greater from SMART program.

Firstly, the PDA are in-line module machines that having three units of Die Attach machines and a unit of Clip Bond machine. The machines were arranged in such a way to fully utilize the capacity of Clip Bond machine, as one Clip Bond machine is having three times the capacity of a Die Attach machine. It means that to operate a lot, three Die Attach machines and a Clip Bond machine are operated at the same time and cannot be separated. It also means that the recipes need to be loaded from each individual machine for four times in order to operate a lot. Due to SECS/GEM communication is treating each machine as an individual machine, the recipe can also being loaded to machine individually, although physically they are in-line. Such situation is consuming time as four recipes need to be loaded to machines in order to operate a lot.

Therefore, SMART program shall plays the role in doing the improvement. It shall be modified for user to select multiple machines and download the recipe to the selected machines. Such program modification shall further improves the recipe download efficiency and hence improves the productivity. Figure 5.1 shows the machine list shall tie up the module machines to be showed up together in order to

enable the multiple machine recipe download, rather than just displaying one machine for recipe download at one time only.
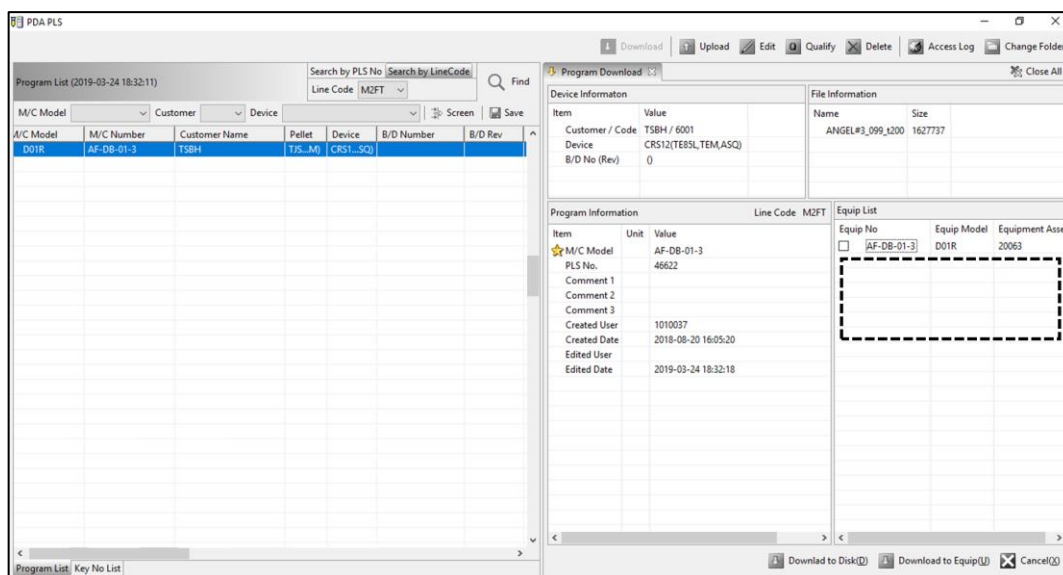
Figure 5.1 Module machine list display area

Besides that, the utilization report is able to display the total utilization by day base only. User is unable to further drill down the data until shift base or hourly base. The report also displayed in raw data only where user is hard to justify the utilization result of each machine. Although SMART Client allows user to download the utilization for further analysis purpose, it is recommended to develop a few more display according to user requirement to minimize their analysis time. The recommended display includes utilization result display by hourly base and plotting Pareto Chart on the utilization performance of each machine. With such display, user could know the machine performance up to each hour, as well as comparing the utilization performance of each machine by viewing the Pareto Chart.

For alarm data, currently SMART Client is able to display alarm description, start time, end time and duration for each machine at selected period. Although the data is already sufficient enough for user to perform machine improvement compared to previous time, but additional alarm data display are recommended to ease the user to perform analysis. The example additional alarm data display are alarm count summary and alarm data display in Pareto Chart.

The improvement proposal shall be considered and proceed with improvement first before fanning out the project to other processes.

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APPENDICES

APPENDIX A: The WBS of SMART Project

Item	In Charge Department
Project Launching	
- Project Scope Definition	IT
- Organization Forming & Job Function Definition	IT, IE, EE, PD, PP, MFG, QA
- Work Breakdown Structure Definition	IT, IE, EE, PD, PP, MFG, QA
- SECS/GEM Protocol Definition	IT
- Architecture Preparation	IT
- SMART Core Structure Design	IT
- Risk Analysis and Backup Plan	IT, IE, EE, PD, PP, MFG, QA
- Machine List, Asset/Inventory/Serial Number Preparation	IT, EE
- Machine SECS/GEM Capability Check	IT, EE
- Machine Upgrade Discussion with Machine Maker/Vendor	IT, EE, PD
- Machine Upgrade Quotation Request	PD
- Layout Preparation	IE
- Infrastructure (Computer, Barcode Scanner) Readiness Study	IT
- Infrastructure (VM Server, LAN, Switch) Readiness Study	IT
- Infrastructure Readiness Quotation Request	PD
- Cost Compilation & Return of Investment (ROI) Calculation	IT, IE, PD
- Project Schedule and Gantt Chart Preparation	IT, IE, EE, PD, PP, MFG, QA
- Budget Requisition with Management	IT
Development	
- PO Issuance	PD
- VM Server Preparation	IT
- LAN Cable & Switch Installation & Workability Test	IT
- Maker/Vendor SECS/GEM Protocol Development	IT
- SMART Core Structure Development	IT
- SMART Core Structure Testing, Review & Debugging	IT
- SMART Core Structure Stabilization	IT
Machine Setup	
- Machine SECS/GEM Setup	IT, EE, PP, MFG
- IP Address Setting	IT, EE
- SECS/GEM Communication Test	IT, EE
User Acceptance Test (UAT)	
- Computer & Barcode Scanner Installation	IT
- System Functionality Test	IT, EE
- System Buy Off	IT, EE, MFG, QA
SMART System Deployment	
- System Deployment	IT, EE
- Education to Production Line Members	IT, EE, MFG, QA
Stability Monitoring	
- System Stability Monitoring	IT, MFG, EE

APPENDIX B: SECS/GEM PROTOCOL

Stream Function	Item
Stream 1: Equipment Status	
S1F0	Abort Transaction (S1F0)
S1F1	Are You There Request (R)
S1F2	On Line Data (D)
S1F3	Selected Equipment Status Request (SSR)
S1F4	Selected Equipment Status Data (SSD)
S1F11	Status Variable Namelist Request (SVRN)
S1F12	Status Variable Namelist Reply (SVNRR)
S1F13	Establish Communications Request (CR)
S1F14	Establish Communications Request Acknowledge (CRA)
S1F15	Request OFF-LINE (ROFL)
S1F16	OFF-LINE Acknowledge (OFLA)
S1F17	Request ON-LINE (RONL)
S1F18	ON-LINE Acknowledge (ONLA)
Stream 2: Equipment Control and Diagnostics	
S2F0	Abort Transaction (S2F0)
S2F13	Equipment Constant Request (ECR)
S2F14	Equipment Constant Data (ECD)
S2F15	New Equipment Constant Send (ECS)
S2F16	New Equipment Constant Acknowledge (ECA)
S2F17	Date and Time Request (DTR)
S2F18	Date and Time Data (DTD)
S2F23	Trace Initialize Send (TIS)
S2F24	Trace Initialize Acknowledge (TIA)
S2F29	Equipment Constant Namelist Request (ECNR)
S2F30	Equipment Constant Namelist (ECN)
S2F31	Date and Time Set Request (DTS)
S2F32	Date and Time Set Acknowledge (DTA)
S2F33	Define Report (DR)
S2F34	Define Report Acknowledge (DRA)
S2F35	Link Event Report (LER)
S2F36	Link Event Report Acknowledge (LERA)
S2F37	Enable / Disable Event Report (EDER)
S2F38	Enable / Disable Event Report Acknowledge (EERA)
S2F39	Multi-block Inquire (DMBI)
S2F40	Multi-block Grant (DMBG)
S2F41	Host Command Send (HCS)
S2F42	Host Command Acknowledge (HCA)

Stream 5: Exception (Alarm) Reporting	
S5F0	Abort Transaction (S5F0)
S5F1	Alarm Report Send (ARS)
S5F2	Alarm Report Acknowledge (ARA)
S5F3	Enable / Disable Alarm Send (EAS)
S5F4	Enable / Disable Alarm Acknowledge (EAA)
S5F5	List Alarm Request (LAR)
S5F6	List Alarm Data (LAD)
Stream 6: Data Collection	
S6F0	Abort Transaction (S6F0)
S6F1	Trace Data Send (TDS)
S6F2	Trace Data Acknowledge (TDA)
S6F5	Multi-block Data Send Inquire (MBI)
S6F6	Multi-block Grant (MBG)
S6F11	Event Report Send (ERS)
S6F12	Event Report Acknowledge (ERA)
S6F15	Event Report Request (ERR)
S6F16	Event Report Data (ERD)
S6F19	Individual Report Request (IRR)
S6F20	Individual Report Data (IRD)
Stream 7: Process Program Management	
S7F0	Abort Transaction (S7F0)
S7F1	Process Program Load Inquire (PPI)
S7F2	Process Program Load Grant (PPG)
S7F3	Process Program Send (PPS)
S7F4	Process Program Acknowledge (PPA)
S7F5	Process Program Request (PPR)
S7F6	Process Program Data (PPD)
S7F17	Delete Process Program Send (DPS)
S7F18	Delete Process Program Acknowledge (DPA)
S7F19	Current EPPD Request (RER)
S7F20	Current EPPD Data (RED)

Stream 9: System Errors	
S9F0	Abort Transaction (S9F0)
S9F1	Unrecognized Device ID (UDN)
S9F3	Unrecognized Stream Type (USN)
S9F5	Unrecognized Function Type (UFN)
S9F7	Illegal Data (IDN)
S9F9	Transaction Timer Timeout (TTN)
S9F11	Data Too Long (DLN)
S9F13	Conversation Timeout (CTN)
Stream 10: Terminal Display	
S10F0	Abort Transaction (S10F0)
S10F1	Terminal Request (TRN)
S10F2	Terminal Request Acknowledge (TRA)
S10F3	Terminal Display, Single (VTN)
S10F4	Terminal Display, Single Acknowledge (VTA)
S10F5	Terminal Display, Multi-Block (VMN)
S10F6	Terminal Display, Multi-Block Acknowledge (VMA)

APPENDIX C: SMART Project Machine List

Machine	Maker	Model	Asset Number	Inventory Number	Serial Number	SECS/GEM Capability	Upgrade PIC
AF-DB-01-1	Canon	D01R	20122	161010002814	DBP1182	Yes	Canon
AF-DB-01-2	Canon	D01R	20062	161010002789	DBP1183	Yes	Canon
AF-DB-01-3	Canon	D01R	20063	161010002790	DBP1184	Yes	Canon
AF-DB-01-4	QEL	CBM-2500	20139	161010002823	MMM18604-B	No	SEMI Integ
AF-DB-02-1	Canon	D01R	21643	161010002881	DBP1453	Yes	Canon
AF-DB-02-2	Canon	D01R	21644	161010002882	DBP1454	Yes	Canon
AF-DB-02-3	Canon	D01R	21645	161010002883	DBP1455	Yes	Canon
AF-DB-02-4	Canon	CB2	21640	161010002879	MTH0305	Yes	Canon
AF-DB-03-1	Canon	D01R	21651	161010002889	DBP1450	Yes	Canon
AF-DB-03-2	Canon	D01R	21649	161010002887	DBP1451	Yes	Canon
AF-DB-03-3	Canon	D01R	21650	161010002888	DBP1452	Yes	Canon
AF-DB-03-4	QEL	CBM-2500	22124	161010002926	MMM16648-B	No	SEMI Integ
AF-DB-04-1	Canon	D01R	21646	161010002884	DBP1461	Yes	Canon
AF-DB-04-2	Canon	D01R	21647	161010002885	DBP1462	Yes	Canon
AF-DB-04-3	Canon	D01R	21648	161010002886	DBP1463	Yes	Canon
AF-DB-04-4	QEL	CBM-2500	22123	161010002925	MMM16646-B	No	SEMI Integ
AF-DB-05-1	Canon	D01R	22099	161010003042	DBP1487	Yes	Canon
AF-DB-05-2	Canon	D01R	22408	161010003043	DBP1488	Yes	Canon
AF-DB-05-3	Canon	D01R	22409	161010003044	DBP1489	Yes	Canon
AF-DB-05-4	Canon	CB2	22100	161010000341	MTH0312	Yes	Canon
AF-DB-06-1	Canon	D310	22675-1	161010003183-1	DBX0117	Yes	Canon
AF-DB-06-2	Canon	CB2	22675-2	161010003183-2	MTH0322	Yes	Canon
AF-DB-07-1	Canon	D310	22784	161010003246-0	DBX0118	Yes	Canon
AF-DB-07-2	Canon	CB2	22785	161010003246-1	MTH0323	Yes	Canon

APPENDIX D: Gantt Chart of SMART Project

No	Item	PIC	Start Date	End Date	Duration (week)
1	Project Launching				
	- Project Scope Definition	IT	WW01	WW01	1
	- Organization Forming & Job Function Definition	IT, IE, EE, PD, PP, MFG, QA	WW01	WW01	1
	- Work Breakdown Structure Definition	IT, IE, EE, PD, PP, MFG, QA	WW01	WW01	1
	- SECS/GEM Protocol Definition	IT	WW01	WW01	1
	- Architecture Preparation	IT	WW01	WW01	1
	- SMART Core Structure Design	IT	WW01	WW01	1
	- Risk Analysis and Backup Plan	IT, IE, EE, PD, PP, MFG, QA	WW01	WW02	2
	- Machine List, Asset/Inventory/Serial Number Preparation	IT, EE	WW02	WW02	1
	- Machine SECS/GEM Capability Check	IT, EE	WW02	WW02	1
	- Machine Upgrade Discussion with Machine Maker/Vendor	IT, EE, PD	WW02	WW02	1
	- Machine Upgrade Quotation Request	PD	WW02	WW02	1
	- Layout Preparation	IE	WW02	WW02	1
	- Infrastructure (Computer, Barcode Scanner) Readiness Study	IT	WW02	WW02	1
	- Infrastructure (VM Server, LAN, Switch) Readiness Study	IT	WW02	WW02	1
	- Infrastructure Readiness Quotation Request	PD	WW02	WW02	1
	- Cost Compilation & Return of Investment (ROI) Calculation	IT, IE, PD	WW02	WW02	1
	- Project Schedule and Gantt Chart Preparation	IT, IE, EE, PD, PP, MFG, QA	WW01	WW02	1
	- Budget Requisition with Management	IT	WW02	WW02	1
2	Development				
	- PO Issuance	PD	WW03	WW03	1
	- VM Server Preparation	IT	WW04	WW04	1
	- LAN Cable & Switch Installation & Workability Test	IT	WW07	WW08	2
	- Maker/Vendor SECS/GEM Protocol Development	IT	WW04	WW07	4
	- SMART Core Structure Development	IT	WW04	WW09	6
	- SMART Core Structure Testing, Review & Debugging	IT	WW09	WW09	1
	- SMART Core Structure Stabilization	IT	WW09	WW10	2
3	Machine Setup				
	- Machine SECS/GEM Setup	IT, EE, PP, MFG	WW08	WW10	3
	- IP Address Setting	IT, EE	WW11	WW11	1
	- SECS/GEM Communication Test	IT, EE	WW11	WW11	1
4	User Acceptance Test (UAT)				
	- Computer & Barcode Scanner Installation	IT	WW11	WW11	1
	- System Functionality Test	IT, EE	WW11	WW12	2
	- System Buy Off	IT, EE, MFG, QA	WW11	WW12	2
5	SMART System Deployment				
	- System Deployment	IT, EE	WW13	WW13	1
	- Education to Production Line Members	IT, EE, MFG, QA	WW13	WW13	1
6	Stability Monitoring				
	- System Stability Monitoring	IT, MFG, EE	WW14	WW15	2

Timeline: Jan'19 (weeks 1–5), Feb'19 (weeks 6–8), Mar'19 (weeks 9–13), Apr'19 (weeks 14–15).

APPENDIX E: SMART Implementation Education Record

	AMKOR TECHNOLOGY MALAYSIA SDN BHD					
				Ref WI No :		
DATE :		TRAINING RECORD		ER NO : DD2A - 18 - 05 - 〇〇		
TITLE **SMART Implementation at PDA Process**				T. 0000086938		
EDUCATION ITEMS : SMART Implementation at PDA Process						
ATTENDANCE :						
NO.	NAME	SHIFT	EMPLOYEE NO.	PROCESS	SIGNATURE	
1	NURUL HASANAH BINTI KAMARUDDIN	C	87372	Separator		
2	LIYANA IZZATI BINTI ROSLI	C	89562	Separator		
3	Sivananthiney %o kumaran	C	88333	MOLDING		
4	NORFADILAH BINTI ABD GHANI	C	96892	MOLDING		
5	NOORDORAN BT SAMSURI	N	9105938	TRAINER		
6	RAHAYU BT ABU BAKAR	C	9520345	MOL		
7	Sarasupathy A/P Ramu	C	9520154	MOL		
8	Premlatha %p Yuvaraj Bupalan.	C	96893	molding		
9	NURUL NADIA BT ZULKEFLY	C	89561	MOL		
10	Amutha A/p Krishnan	C	9520081	EOL		
11	Sharmila A/p Subramaniam	C	092015C	EOL		
12	V.DHANALETCHUMY	C	9024744	EOL		
13	ANGOLA B NAIN	C	1010046	Supervisor		
14	MOHD ZAINAL B. KAMARUDIN	C	9510098	MOL		
15	AHMAD BAIDHAWI B. MOHD NAJMUDDIN	C	86284	EOL		
16	GANESH N/C SELVARAJU	C	83555	EOL		
17	AZHAR JAIS	N	1210155	EOL		
18	MOHD SHAHREL B. AIMAN	N	1110032	Process		
19	ROSMAYATI BT MINGON	C	8924570	EOL/MOL		
20	NUR SYAFIQAH BT MOHD YUSOF	B	88996	MOL		
21	Thanaletchumy. S	B	9420349	EOL		
22	NORLIZAH SAHANUDDIN	B	9125103	EOL/MOL		
23	M. Jayaletchumy	B	9024918	EOL		
24	Nithyasuangu	B	8410998	MOL		
25	Thanbelan A/L Krishnasamy	B	86927	EOL		
26	SYAHRIR ASRAF BIN NADZRI	B	1210231	MOL		
27	muniammal A/p Ramakrishan	B	1220259	MOL		
28	Jaya Raj Sivagurunathan	B	9211576	Gen		
29	kaupal availi	A	88993	mol		
30	SHARIOATUL AINMA SHARIF	A	86190	EOL		

TRAINER	EMPLOYEE NO.	SIGNATURE	RECORD UPDATED BY	DATE
Ng Pei Chai	1010037		IZAN	

AAA : Refer to Line Company — DSAW, IC, DD1A, DD1B, DD1C / GE, QC, DD2A, DD2B, DD8
BB: Refer to Year — 16 = 2016, 17 = 2017
CC Refer to Month — 01 = Jan, 12 = Dec
DD Refer to Serial No — 001, 002

AMKOR TECHNOLOGY MALAYSIA SDN BHD

	Ref WI No :

DATE :	TRAINING RECORD	ER NO : DD2A - 18 - 05 - 032

TITLE SMART Implementation at PDA Process

T.0000086938

EDUCATION ITEMS :
    SMART Implementation at PDA Process

ATTENDANCE :

NO.	NAME	SHIFT	EMPLOYEE NO.	PROCESS	SIGNATURE
1	MUHAMMAD JJZAIDI	A	86283	EOL	
2	Kannan 9/1 Gopi	A	1210009	MOL	
3	AHLS SYAFIGAH	A	89941	SEPARATOR	
4	karpagavalii.	A	88991.	MOL	
5	NURUL IZYAN BT SHAMSON	A	83334	MOL	
6	THANALETCHUMY A/P VELLOO	A	9520013	EOL	
7	MUHAMMAD NAJWAN SYAFIQ BIN NAZIRI	A	84233	MOL	
8	Abdul Rasid Bin Dominikus	A	9510020	SV	
9	SYED SUFIAN BIN TUAN CHIK	A	9710016	EOL	
10	Mohd Ridwan B Musa	N	1210194	EOL	
11					
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30					

TRAINER	EMPLOYEE NO.	SIGNATURE	RECORD UPDATED BY	DATE
Ng Pei Chai	1010037		IZAN	

AAA : Refer to Line Company	BB: Refer to Year	CC Refer to Month	DD Refer to Serial No
DSAW GE	16 = 2016	01 = Jan	001
IC QC	17 = 2017	:	002
DD1A DD2A	:	:	:
DD1B DD2B	:	12 = Dec	:
DD1C DD8			

APPENDIX F: Recipe Control Monitoring Result

Lot	Package	Family	Key No	Lot No	St/Ed	Process	Lot Gross	Lot Net	Defect	Yield	Machine	Pop No	Operator Name	Performed by	Cycle Check Name	Judge
1	SOD123PAST	STPS1L60(ER,ST,AD)	THUZi8	9K83500A	Lot-St	Die Attach	32586	32586	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS1L60(ER,ST,AD)	THUZi8	9K83500A	Lot-Ed	Die Attach	32586	32514	72	99.78%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	OK
2	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi9	9K83500B	Lot-St	Die Attach	144234	144234	0	100%	AF-DB-01	1018	WAHIDAYU RAFIDAH BINTI YAACOB	NUR ALYAA BINTI ARIFIN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi9	9K83500B	Lot-Ed	Die Attach	144234	144166	68	99.95%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NUR ALYAA BINTI ARIFIN	(9657) SFA Mount App Check-O	OK
3	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi2	9K83500B	Lot-St	Die Attach	144428	144428	0	100%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi2	9K83500B	Lot-Ed	Die Attach	144428	144428	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	OK
4	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi3	9K83500B	Lot-St	Die Attach	112260	112260	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi3	9K83500B	Lot-Ed	Die Attach	112260	112260	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	OK
5	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi5	9K83500D	Lot-St	Die Attach	32150	32150	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi5	9K83500D	Lot-Ed	Die Attach	32150	32114	36	99.89%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	OK
6	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi4	9K83500C	Lot-St	Die Attach	15935	15935	0	100%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS2H100(ER,ST,AD)	THUZi4	9K83500C	Lot-Ed	Die Attach	15935	15910	25	99.84%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	OK
7	SOD123PAST	STTH1R02(ER,ST,AD)	THUZi6	9K83500E	Lot-St	Die Attach	52716	52716	0	100%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	-
	SOD123PAST	STTH1R02(ER,ST,AD)	THUZi6	9K83500E	Lot-Ed	Die Attach	52716	52644	72	99.86%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	NURAQILAH SYAKIRAH BINTI MISWANDI	(9657) SFA Mount App Check-O	OK
8	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi5	9K835009	Lot-St	Die Attach	142816	142816	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi5	9K835009	Lot-Ed	Die Attach	142816	142744	72	99.95%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	OK
9	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi4	9K835009	Lot-St	Die Attach	143051	143051	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi4	9K835009	Lot-Ed	Die Attach	143051	143051	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	OK
10	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi6	9K835009	Lot-St	Die Attach	111275	111275	0	100%	AF-DB-01	1018	ZARINA BINTI DIRAN	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	-
	SOD123PAST	STPS1L60(ER,ST,AKD)	THUZi6	9K835009	Lot-Ed	Die Attach	111275	111203	72	99.94%	AF-DB-01	1018	NURAQILAH SYAKIRAH BINTI MISWANDI	ZARINA BINTI DIRAN	(9657) SFA Mount App Check-O	OK