APPLICATION OF PULL/KANBAN SYSTEM TO REDUCE INVENTORY AND LEAD TIME IN A MANUFACTURING SYSTEM

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June 2017

This dissertation is submitted to

Universiti Sains Malaysia

As partial fulfillment of the requirement to graduate with honors degree in

BACHELOR OF ENGINEERING

(MANUFACTURING ENGINEERING WITH MANAGEMENT)

School of Mechanical Engineering

Engineering Campus

Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Statement 1

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ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude to those offer guidance and helping to complete the project. I am very grateful to my supervisor, Dr Hasnida Binti Ab Samat whose her encouragement, precious advice and guidance for the project contribute immensely to the completion of the project. I respect her for her valuable guidance and understanding to students during the project.

Besides, I am very grateful to the participating company for providing this opportunity to complete such challenging project. I acknowledge with thanks the timely assistance, suggestion, and motivation which I have received from Mr. Chiang Yoong Fatt. He is one of the backbone and the guide thought this project.

Lastly, million thanks to all my beloved family, friends and all individual who lend me helping hands during my difficulties. Their contribution and encouragement are the most valuable during the project. Once again, thank you very much.

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ABSTRAK

Kertas kerja ini membentangkan pengurangan masa pengeluaran dan kos inventori dalam pengeluaran produk yang tahap pelbezaannya sederhana dan jumlah pengeluaran yang rendah. sistem Tarik atau sistem Kanban. Kilang ini adalah kilang pemasangan mesin manual kedudukan tetap. Keadaan kilang sebelum penambahbaikan seperti masa pengeluaran mesin dan masa setiap proses pembuatan telah dikumpulkan daripada kajian masa dan telah dianalisiskan. Carta Pareto dan carta Pai digunakan untuk menunjukkan proses yang mempunyai masa yang panjang. Proses pemasangan submodul diberi penekanan kerana mereka memerlukan bahan mentah daripada proses sebelumnya. Kos inventori pula adalah daripada perisian ERP syarikat. Dalam peringkat reka bentuk, sistem tarik bercampur yang sesuai dengan kilang tersebut telah direka bentuk. Submodul dinilai berdasarkan beberapa kriteria seperti tahap perbezaannya, saiz, masa dan sama ada mereka boleh dipasang sebelum pemasangan seluruh mesin supaya keputusan dapat dibuat dengan pendekatan Design of Experiment (DoE) dan pemodelan simulasi. Kuantiti Kanban dikira dengan formula dan kuantitinya ditetapkan dengan pendekatan kualitatif, kuantitatif dan DoE juga. Prosedur kerja, langkah dalam pengaliran maklumat dan bahan mentah dalam system Kanban telah direka bentuk mengikut sumber manusia yang sedia ada dan kemahiran mereka. Hasil selepas pelaksanaan Kanban menunjukkan pengurangan dalam masa pengeluaran sebanyak 45.97% iaitu daripada 33.72 hari sehingga 20.17 hari dan pengurangan inventori kos sebanyak 28.49% iaitu daripada RM 132.857,14 RM 9500,00. Selepas pelaksanaan Kanban mencapai kestabilan, Standard Prosedur Operasi (SOP) disediakan penambahbaikan dapat dikekalkan,

ABSTRACT

This thesis focused on manufacturing lead time and inventory cost reduction in medium mix low volume production with Pull system or Kanban system. The production is a fixed position machine manual assembly line. The initial condition of the production such as the manufacturing lead time and process lead time was collected from time study and the data was analyzed. The submodule assembly processes were given attention as they consume raw material. Inventory level was collected in terms of cost from the ERP software of the company. In design stage, a mixed pull system which consisted of Kanban system and sequential pull system was designed. The submodules were evaluated based on some criteria such as customization level, size, lead time and whether they can be assembled externally and then were decided by using simulation and Design of Experiment (DoE). The quantity of Kanban was calculated and decided by using qualitative or quantitative approach and Taguchi method as well. The work procedure, information and material transfer steps were designed according to the available human resource and their skill. The result after Kanban implementation showed 45.97% lead time reduction from 33.72 days to 20.17 days and 28.49% inventory cost reduction from RM 132857.14 to RM 9500.00. After the termination stage stabilized, a Standard Operating Procedure(SOP) was prepared to maintain the improvement made.

CHAPTER ONE: INTRODUCTION

1.1 Inventory Control & Kanban System

Inventory Control is a critical issue in industry because it contributes to the performance of production and cost. In many cases, inventory is necessary to smoothen the production flow. [1]However too much inventory ends up with creating a safe zone where the problems are hidden beside increasing the inventory cost. [2]This is one of a characteristic of push system. Too little inventory is also a disaster because the production is not capable to react fast to quickly change customer demand. The compensation between inventory, cost and demand factors is a huge challenge for the industry. [3]

Kanban is a suitable solution for this issue because Kanban links inventory control and customer demand together [4]. Kanban is a Japanese word where Kan means “visual” and Ban means “card”. [5] Kanban is a pulling system where the manufacturing process withdraws the parts from preceding process and then the proceeding process will only produce the exact amount that is withdrawn. [6] It is also referring as a signal that triggers the production to produce parts that are consumed. [7]Different signal can be used for example cards, cloth, electronic signal etc. Kanban is a lean tool to achieve JIT production and reduce idle time. It is to ensure the production produce the right product of right amount at the right time. [8]

The origin of the Kanban starts in the late 1940’s when Mr. Taiichi Ohno discovered the benefits of the supermarket concept in America and decided to adopt it in the Toyota organization. [7] The disadvantage condition of Japan due to insufficient of investment model and raw material force them to pay best effort to produce high quality product at lowest cost. Thus, waste is the main concern for Toyota. [9] For traditional mass production in Toyota, operations run according to the schedule. Inventory buffer exists between departments to keep downstream process busy. This leads to overproduction which is one of the 7 wastes. As a compromise between the ideal of one-piece flow and push system, Ohno created small “stores” of parts between the operations to control inventory. The Kanban Signal is used to indicate the parts are used and need to “buy” them from upstream process. The implementation eliminates the overproduction problem beside decrease the needs for a sophisticated inventory tracking system. [10]

Kanban improves the flow but reduces the buffer needed. Thus, the inventory level is reduced. Kanban also improves flexibility and responsive of the production to change in demand. Secondly, Kanban helps to reach JIT production as well as increasing the efficiency. [11] Kanban implementation is a full success in the automotive industry. However, the idea of Kanban is not only limited to production, its application also benefits various field. The implementation should be modified to fit the application at different field. [12] For example, Agile Kanban Boards or Scrum use the idea of Kanban in project management. [7]

1.2 Research Objective

The two objectives are as below

- To reduce the manufacturing lead time with Kanban implementation
- To reduce the inventory level in production with Kanban implementation

1.3 Problem Statement

The main issue in this research are high manufacturing lead time and inventory level in the production. Other than reducing the output, high lead time reduces the responsive to the customer demand and inability to ship the product just in time. Additionally, high lead time also contributes to high Work-In-Progress(WIP) inventory in production and inventory cost. Ideally, every process strives to overcome these two problems to increase customer satisfaction by implementing Automatic Manufacturing System, Work Study, Kanban implementation, Single Minute Exchange of Die (SMED) or other methods.

1.4 Scope of Work

The scope of the study is limited to the manual assembly production of a model of machine vision inspection machine. Time study and relevant data of current condition will be collected to design a suitable Kanban system for this production. In this context, manufacturing lead time and inventory level (inventory cost every month) are used as performance measure for the research. There are different approaches to improve this low volume medium mix production, however, the study will focus on designing the Kanban system for the production. Several alternative solutions will be proposed and then are simulated with WITNESS 14 simulation software to evaluate its feasibility and effect before real implementation. The best solution is chosen after optimization with Minitab. Then, the chosen solution will be implemented in the manual assembly site. Finally, the time study and data collection will be conducted again to evaluate the performance after Kanban implementation

CHAPTER TWO: LITERATURE REVIEW

There are two types of systems used for material flow or inventory control which are pull system and push system. The traditional push system produces the parts according to the schedule where the preceding process supplies the parts to its subsequent process. The scheduling rule such as First in First Out (FIFO) or Earliest Due Date is used to decide the order of production. [13]. For push system, jobs on entry into the system are queued at the first required process. It has no limit on the amount of work in process(WIP) in the system. [14]. Thus, it has high tendency to store a large amount of inventory so that they are capable of adapting the fluctuating customer demand. This system leads to dead stock, extra equipment, low utilization and surplus workers. It requires frequent re-scheduling to increase the productions' flexibility but at the same time increase the workload. [15].

The pull system introduced by Toyota is the opposite of traditional push system. The example of pull system is Kanban system. The idea of Kanban originates from the supermarket concept in America whereby the subsequent process "buys" the material from upstream process. This system eliminates people from withdrawing too much or too soon from the upstream process. The most significant difference of pull system with push system is that pull system limits the inventory level and it works backward from the customer. It starts when the customer order pulls the finished goods and then the signal is transferred to the previous stage to replenish the withdraw product. [16]. The process must not produce output when there is no Kanban signal. [6] The production can only resume when WIP level is lower than the upper limit and the production receives the Kanban signal from its subsequent station. [13]. Kanban can be referred to both system of procurement or the signal issued for production to start. In Toyota, the whole operation which is using Kanban is also known as "Kanban" system. [10]. The Kanban signal can be in various form such as cards, empty bins, poster, cloth, e-Kanban card and so on. In books or articles, Kanban is also known as supermarket method as well because the concept of Kanban originates from the supermarket. [8]

Kanban is one of the lead tools to create continuous flow. The continuous flow is significant to encourage the realization of Just-In-Time (JIT) manufacturing. It means that all the processes have accurate timing and correct quantity. JIT manufacturing can eliminate the waiting and queueing that contribute to the increase of buffer and inventory level. [15]. Kanban focus on minimizing the inventory level and supply the parts at right type, right quantity, and right time. The application is beneficial to management, business, or production of the organization. Kanban system helps to visualize the work and highlight the abnormal case within the process. It shows the status quo of the process to enforce fast action if any problem occurs. If the problem is not solved, the whole line must be stopped. Secondly, Kanban reduces the work in progress inventory (WIP) or buffer. [17] Unlike push system, Kanban limits the level of inventory and thus eliminate overproduction issue. [11]. Inventory is one of the seven wastes of lean manufacturing because it increases the cost and hides the problem. The inventory is like the level of sea. Kanban system reduces the maximum inventory level and then exposes the rocks below. [18]. Thirdly, Kanban improves the process efficiency by smoothening the process and eliminating the waiting time. Continuous flow is created in production and thus leads to simplification of work in the production planning. [11]

By decreasing waiting time as mentioned above, Kanban system contributes to the reduction of manufacturing lead time. JIT production increases the availability of the material and smoothens process flow in Kanban system. [19]. Manufacturing Lead Time (MLT) is the total time required to process a given part or product. Lead time is commonly selected as the performance measure of the production. [20]. Lead time reduction is the common goal in the industry because shorter lead time creates liquidity to the system. This is desirable in terms of risk management. [21] Lead time reduction leads to lower down the buffer level and thus contribute to the reduction of inventory cost. [11]. From here, the pull system can reduce the 3 out of 7 wastes which are overproduction, waiting and inventory. [18]

The Kanban system encourages continuous improvement in the production. When the Kanban system stabilizes, improvement should be done to reduce the allowed inventory level from time to time. Reduction of buffer makes the problem float out of the water level. This action will force the further improvement of the process to be more efficient. [15]. The implementation of Kanban system shows positive result in performance many companies. For example, in Toyota, the Kanban system makes full use of workers' capabilities. Utilizing this system makes Toyota has lesser rely on the electronic computer but still increase in efficiency. [9].

The main 2 types of Kanban used are withdraw Kanban and production-ordering Kanban. The withdraw Kanban signal contains the information about the types and amount of product withdraw from preceding process. In reverse, Production-ordering Kanban specifies the types and amount of product that should be produced by preceding process. Normally, two types of Kanban are used together in the production. The flow of Kanban system starts with the operator takes the withdraw Kanban from the post box to preceding process to withdraw the needed parts at listed quantity as shown in Kanban card. He detaches the production ordering Kanban which was attached to the full pallet and put it in the appropriate post-box belonging to that process. Then, the worker attaches withdraw Kanban to the full pallet (which he just withdraws) and bring it back to his own process area. Back to preceding process area, the Production-ordering Kanban is removed from the post-box and production starts to replenish the parts according the information on the Kanban. The process flow of Kanban is as figure below [22]. There are also other types of Kanban for various application such as Express Kanban, Emergency Kanban, Job-Order Kanban and so on. The working mechanism may be different but the main concept is same for all type of Kanban. [15]

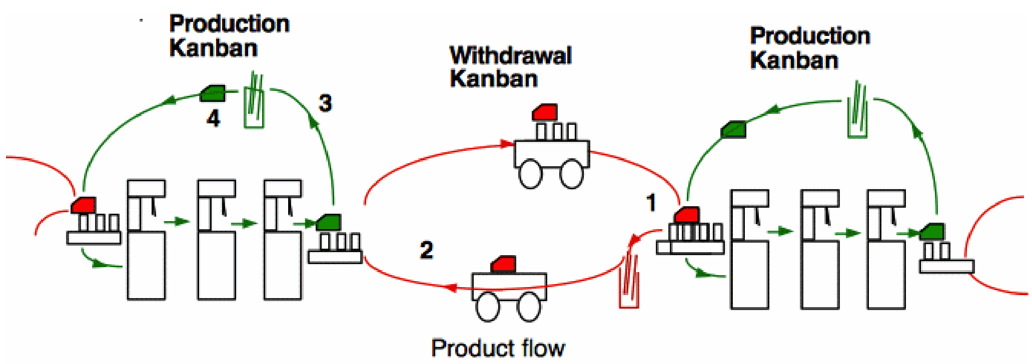

Figure 2. 1 Kanban Process Flow

Adapted from LEAN or JUST-IN-TIME MANUFACTURING, 2016, Retrieved November 3, 2016, from http://thing.cs.usm.maine.edu/~zanerj/330/readings/jit/jit.html

There are similarities between Kanban system and inventory control system. Both set upper limit to the inventory level. [15]. For inventory control, the purpose is to seek the balance between the risk of stock out and the cost of carrying stock. By reaching this goal, it is important to determine the most optimum quantity of inventory and maintain the inventory at this level [2]. There are 4 types of inventory that is present in the production site. This includes raw material, in-process inventory (WIP) and finished product and Maintenance/repair/ operating supply (MRO) inventory. Holding extra inventory is to buffer the variation in production and to reduce the risk of stock out. However, storing too much inventory will increase the cost which consists of the cost of the inventory cost itself, storage cost, cost of possible obsolesce or spoilage [3].

The implementation of Kanban should follow its rules strictly to ensure its effectiveness. The consequences of not following the Kanban strictly is overproduction and thus increase inventory. However, people tends to store the inventory to buffer the variety and make the thing easier. For example, in one case Mr. Ohno thundered because someone pulled the material too early without Kanban. Thus, discipline to follow the rules is the key point to ensure successful Kanban system. [9]

The rules of Kanban are as below:

Rule 1: The subsequent process should only withdraw the necessary product from the preceding process in the correct quantity and at the correct time.

This means that any withdraw of material that does not follow Kanban for example type of material, timing and quantity is prohibited. Kanban should always be attached to the product.

Rule 2: The preceding process should only produce the products in the correct quantity withdrawn by the subsequent process.

The preceding process should only start production prior to Production-ordering Kanban. In another way round, the process is prohibited to start the production when the Kanban is full (before the subsequent process withdraws the Kanban). Any production output different from the information on Kanban is forbidden.

Rule 3: Defective products should never pass to the subsequent process.

This rule is very important as whole Kanban will be destroyed if disobey this rule. The defective product will stop the subsequent process as they don’t have the extra product to replace it. Also, the defects need to go back to preceding process for rework. It affects the scheduling of Kanban system.

Rule 4: The number of Kanban’s should be minimized

Kanban is the maximum inventory that can be stored. Storing inventory is not good due to cost increment and hiding up the problem. Therefore, the level of maximum inventory should be reduced when the system stabilizes. Reducing the number of Kanban pull the production out of its safe zone and force continuous improvement.

Rule 5: Kanban should be used to adapt small fluctuation in demand.

One of the Kanban characteristics is its adaptability to sudden demand change or emergency happen. However, it is not capable to absorb high fluctuation in demand. For example, large seasonal change in demand. In this case, the production line should be rearranged by computing again all the cycle time and resources. [15]

Today, many organizations implement Kanban or pull system in their production to improve their efficiency and flexibility. Real implementation is always the main concern for them. There are some researches done to study Kanban implementation in various type of production and the effect to the productions. For example, there is a case study done by to develop the Kanban system at the local manufacturing company in Malaysia. The research was about the implementation of Kanban to high volume and medium variety production. They gathered the relevant information required of a selected company, calculated the quantity of Kanban and designed the Kanban system and rules. In data collection stage, they analyzed the process flow and collected data included the working hours, change over time, cycle time, and forecast demand. Then, the Kanban signal was designed which included Production Ordering Kanban card and Part Withdrawal Kanban card. The implementation showed great improvement in performance. The lead time was reduced by 40%, inventory (WIP and finished good inventory) was minimized by 23-29% and the finished good area was optimized by 4% They concluded that implementation of

Kanban system improves manufacturing performance by creating synchronization between process line in system and customer needs. Kanban is significant in approaching JIT production. [23]

Another study was done by Maryam And Davood to study the feasibility of Kanban system in a selected organization to approach JIT production. The company selected had been implemented lean manufacturing system and the study was to introduce a suitable Kanban model and then evaluate its performance. In the research, to design the Kanban system, the Kanban card used was designed. Same as case study above, the number of Kanban was calculated and evaluated whether it is suitable to use under busiest and hardest mode. The input of the process which is the manpower was managed by specifying the responsibility of the technician and arrange the work procedure for the technician. This research shows that the Kanban system design must be very accurate and require careful planning. It won't success without the cooperation between employees and managers, the implementation of Kanban shows the positive result in efficiency and JIT production. [24]

Kanban is suitable to be implemented in high volume low mix production or repetitive production. [25] There is a fact that pull system gives a lower performance in high product mix production because it is only suitable to absorb sudden demand change [26] [27]. Research by Eduardo even mentioned that lean tool including Kanban is not suitable for the environment that is low quantity, high variety of product and variable demand [28]. However, the organization nowadays must be responsive and flexible to quick change in customer demand by offering more product variety. They face the challenge in dynamic changing demand. Remigiusz, Robert and Tomasz studied about the implementation of Lean Manufacturing in High mix production environment. One of the lean tools they used was pull system or Kanban system. The pull system was implemented with the hope of decreasing the inventory level and improve the availability of the components for assembly. The common problem faced by the companies using ERP system is the frequent change of database in the system due to fluctuating customer demand. As the result, the workload increases to manage the ERP database, high inventory level and low availability of components when needed. The lead time increases because they suffer from the raw material shortage. The implementation of pull system solved these problems. The modified supermarket pull system was designed to limit the inventory level and provide the material to customer process at the right quantity and right time. In data analyzing stage, the customer demand for all type of components were analyzed. The components were divided into three categories by using ABC analysis [29]. Group A was the high-runners which had the highest demand among three groups. Group B was medium runners in which their consumption was lower than the group A. Group C, the low-runner were needed rarely and in very low volume. Group B was further divided into group B1 where the consumption was regularly but rarely and group B2 where the consumption is irregular and in small volume. Mixed pull system was installed. Group A and Group B1 material used Kanban system whereas Group B2 and Group C used sequential pull-system. The material which had high volume or regular order was chosen to use Kanban. The research concluded that the lean tool or specifically Kanban was successful in high mix production as well but the modification is needed to fit the situation. The result of the improvement showed improvement in productivity of assembly department by 33% and reduction in floor space needed by 50%. [19]

The implementation is not only limited to automotive industry. Nowadays, many organization from various field and background use Kanban in their management. For example, Pixar, Zara, Spotify, and video game industry. [12]. Before implementing Kanban, the culture of Lean thinking needs to be created in the working environment. All employee should have the spirit of continuously improve the process or product instead of hiding the problem. In Toyota, it is impossible for the worker to hide the problem because Kanban will visualize the trouble. Any problem occurs may cause the whole line to shut down and thus force the workers to solve the problem. [10] The implementation of Kanban may be different for each company, but the main concept and thinking is the same for all company.

CHAPTER THREE: METHODOLOGY

3.0 Research Phases & Steps

The flow chart of the research was shown in Figure 3. 1 below. The details will be discussed in the next section. There were 4 Phase and 11 steps for implementation plan. The 4 phases were Planning Phase, Design, Evaluation and Optimization Phase, Implementation and Monitoring Phase and lastly Finalize and Standardize Phase. The tools used during four phases included flow chart, Pie chart and weightage rating system. The three software that were used for the project were Microsoft Visio, WITNESS 14 and Minitab. The usage of tools and software for each step will be discuss in the next sections. Most of the material was needed in Phase 3 which is Implementation and Monitoring Phase. The example of materials included the grey bin to store the Kanban material, paper, laminating film for labeling, Kanban signal and material checklist.

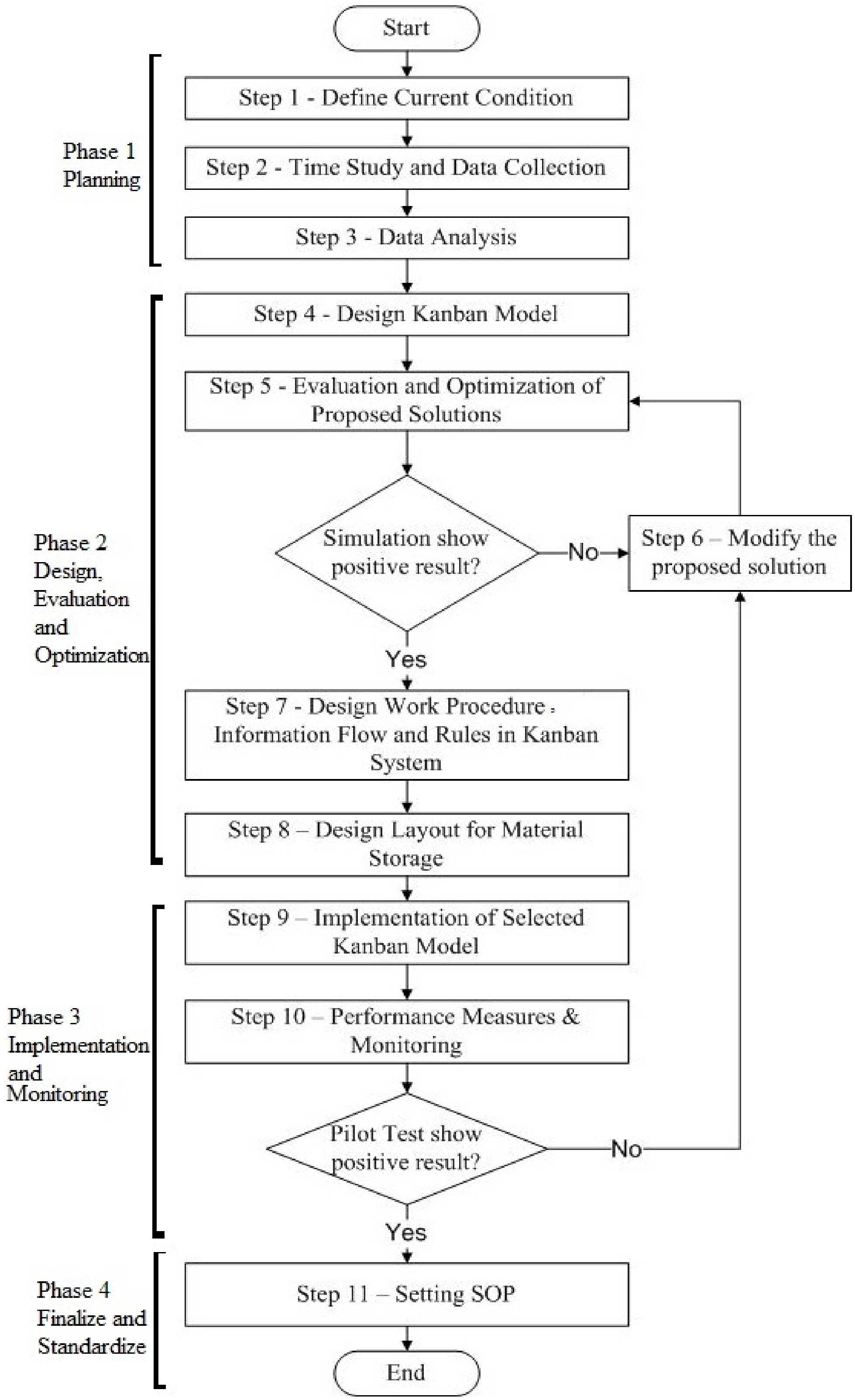

Figure 3. 1 Flow Chart of the Project

3.1 Step 1: Define Current Condition

This step was conducted to have a full understanding of the condition, status quo, and the details of the production site. The information listed below was collected.

a. Type of production

   (The example included Manual or Automated production and Continuous or Discrete production.)

b. Sequencing Rule used in the production

   (How the production handles the order? For example, FIFO rule or Earliest Due Data (EDD) of the order.)

c. Product variety and volume of production

d. Demand of the company

   (The demand of the company was defined as the desired capacity that the production should have. This demand quantity was decided by the stakeholder.)

e. Manufacturing Process and standard process lead time

f. Production Layout

   The layout of the production was drawn in Microsoft Visio.

g. Problem faced in the production

   The methods that were used to determine the problem are Gemba Walk and interview from the stakeholders which include the operators and engineers. Gemba or Gemba walk is a Japanese term meaning “the real place”. The concept of Gemba Walk means that real observation on the production site should be done in order to have a clear and comprehensive view of the problem they face. [30]

3.2 Step 2: Time Study and Data Collection

The data listed in Figure 3. 2 was collected with the listed tools. The data that were collected included Manufacturing lead time and the Inventory level in terms of cost. They were decided as the performance measure for the project.

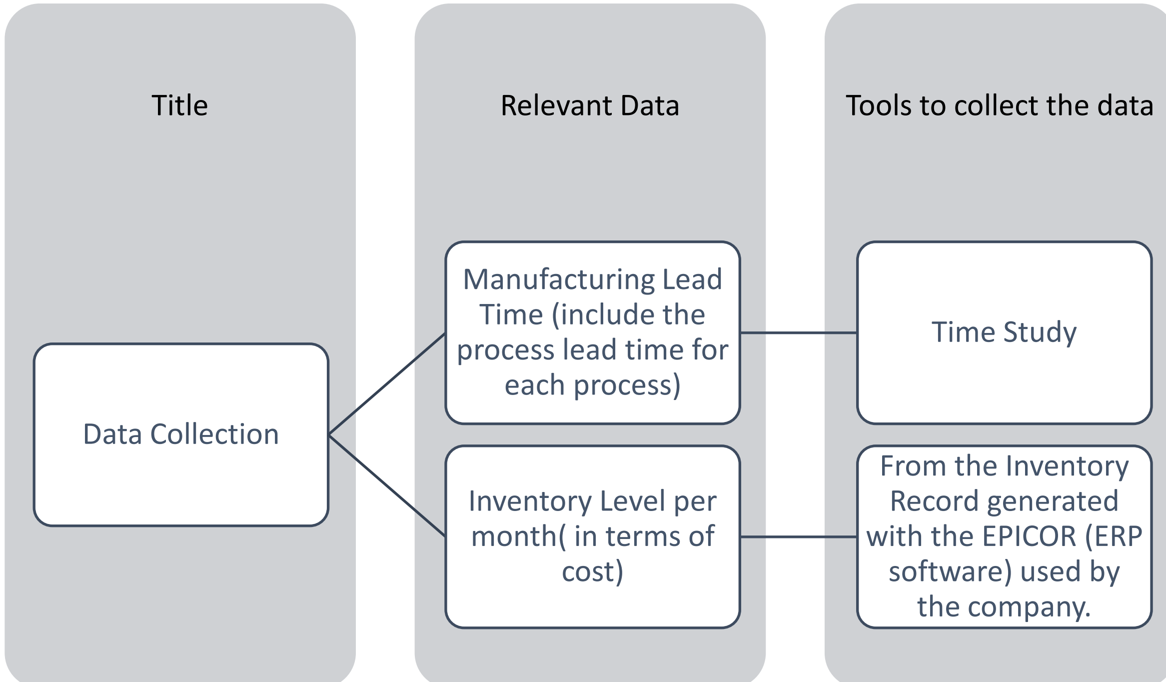

Figure 3. 2 Relevant data and the tools used for data collection

Time study was used to collect the manufacturing lead time. It is one of the methods used in work measurement to set the basic time or the standard time to conducting a work. In time study, the steps that should be done included observing the work, recording the manufacturing process and the time for the operator to complete the work. Any timekeeping device is suitable to be used. [31]. In this case, stopwatch and the digital watch were used to recording the time.

The time study was conducted with the time study sheet templates in Figure 3. 3. Machine ID, stations, process lead time, the time it started and ended the process were included in the time study sheet. Each machine had its own sheet of time study. The operator who done the work was recorded in the time study as well. The data collection started from July to September 2016.

Time Study Templete												
Machine ID												*ID of the machine set by the company*
Station												
Bil	Work Element	Operation					Start		Stop		Duration(hour)	Note
							Date	Time	Date	Time		
*	**Operation Start**	◯	⇒	□	D	∇					0:00	
1		◯	⇒	□	D	∇					0:00	
2		◯	⇒	□	D	∇					0:00	
3		◯	⇒	□	D	∇					0:00	
4		◯	⇒	□	D	∇					0:00	
5		◯	⇒	□	D	∇					0:00	
6		◯	⇒	□	D	∇					0:00	
7		◯	⇒	□	D	∇					0:00	
8		◯	⇒	□	D	∇					0:00	
9		◯	⇒	□	D	∇					0:00	
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13		◯	⇒	□	D	∇					0:00	
14		◯	⇒	□	D	∇					0:00	
15		◯	⇒	□	D	∇					0:00	
16		◯	⇒	□	D	∇					0:00	

Figure 3. 3 Time Study Sheet Template

3.3 Step 3: Data Analysis

The data collected from Step 1 and Step 2 was analyzed to determine the design parameter of Kanban system. The output as below was obtained from data analysis.

a. Manufacturing Lead Time and the Process Lead Time

The data collected in time study was analyzed to obtain average manufacturing lead time and the process lead time. Control Chart and pie chart were used to represent the data collected. The process that involves material flow was notified as the Kanban implementation involve material flow. The lead time of these process is needed in Kanban Design stage.

b. Operation Time and Non-operation Time

The time collected was classified as operation time and non-operation time when the machine is left idle. The operation time is considered as the value added time which is defined as the process is what your customer wants and add value to the product or service you provide. Non-operation time is considered as nonvalue-added time which is considered as the waste of resource. [32]. The cause of non-operation time was determined.

c. Job Scope and skills of the Human Resource

The skill and job scope of the current stage were collected based on observation and interview during section 3.2.

d. Inventory cost and mean value.

3.4 Step 4: Design Kanban Model

Suitable Kanban model that suits the production was designed. Figure 3. 4 was the flow chart for the Design Kanban Model. Step 4 has 4 sub-steps to develop some alternative solutions. The decision was based on qualitative and quantitative approach.

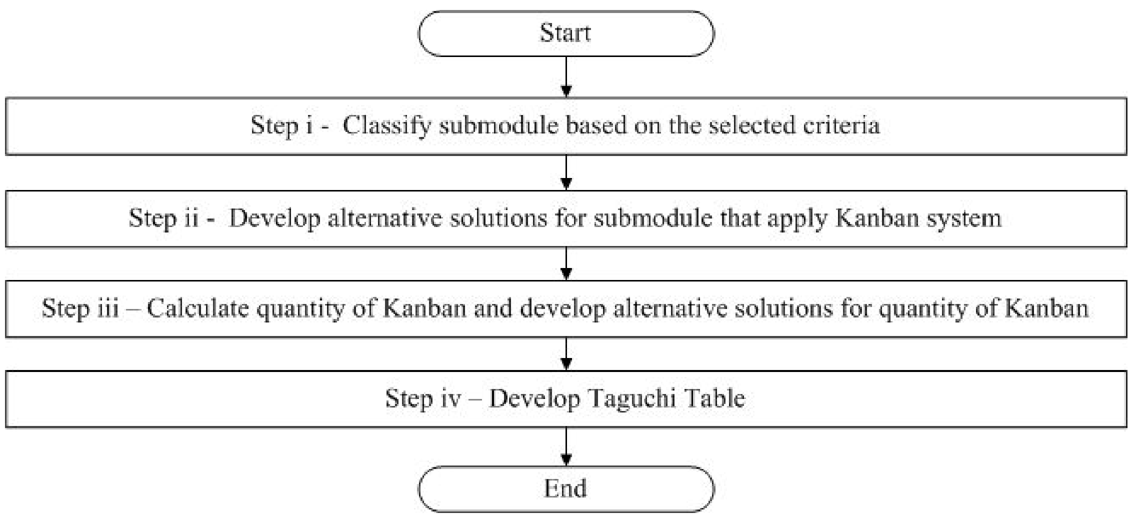

Figure 3. 4 Flow Chart for Design Kanban Model for Production

3.4.1 Step i: Classify submodule based on the selected criteria

The submodules were evaluated based on some criteria to choose which submodule to implement Kanban. The criteria were described as below. The relationship of submodule with the criteria in Table 3 are decided based on the information from the section 3.2 and section 3.3 and the qualitative decision from the stakeholder.

a. Customization Level

The submodules were classified into two groups which were high variety submodule and low variety submodule. The classification of the submodule was based on the qualitative decision from stakeholder, the sales quantity of different model and the BOM list for each model.

b. Size

The limited space for material storage and the size of bin become the constraint in choosing the materials that can be stored as Kanban. The judgement was based on straight observation and qualitative decision.

c. Lead Time

The lead time of the assembly of submodule varies for each submodule. The lead time of the bottleneck will affect the manufacturing lead time of the machine profoundly. Thus, the assembly process which has long lead time was the concern of the project.

d. Precedence relationship of submodule assembly process

Some components can only be assembled during the full assembly and integration of the whole machine. Also, the source of submodule determines whether it can be assembled internally or externally. This step was significant in designing the process flow for Kanban system.

3.4.2 Step ii: Develop alternative solutions for submodule that apply Kanban system

Two decision-making approaches were used to select the group of submodules to use Kanban system which were quantitative approach and qualitative approach as shown in Figure 3. 5. The tools for the quantitative approach was weighted rating system. This is a rating system based on some criteria and the weightage was assigned to the criteria to increase the difference of the total score for each option.

The first step in decision making was to list out the criteria and assign the weightage to every criterion. The score was given to each submodule based on their relationship with the criteria. The weighted score was done by multiplying the score with the weightage. The total score for each option was calculated and then were ranked in descending order. Three alternative solutions related to the submodule to apply Kanban were proposed based on qualitative approach.

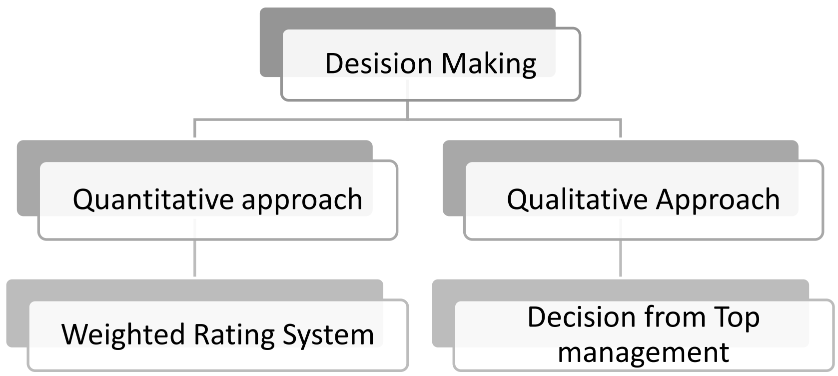

Figure 3. 5 Decision Making Approach

3.4.3 Step iii: Determine the quantity of Kanban

The two approaches that were used include qualitative and quantitative approach. The quantitative approach was to calculate the Kanban quantity with the formula below [3]

$$\text{Number of Kanban} = \frac{\text{Demand during lead time+safety Stock}}{\text{Size of container}}$$

Three alternative quantity of Kanban were developed based on the calculation above and the qualitative decision from the stakeholders of this project.

3.4.4 Step vi: Develop Taguchi Table

From the three alternatives each from section 3.4.2 and section 3.4.3, a Taguchi table was developed. L9 Taguchi design was selected because of 3^2 (3-Level Design with 2 controllable factors). There are nine models in the Taguchi table.

3.5 Step 5: Evaluation and Optimization of the Proposed Solutions

Nine experiments with different factors combination were designed based on the Taguchi table generated in section 3.4.4 above. Nine simulation models were constructed and simulated with WITNESS 14 simulation software. The performance measure in the simulation was manufacturing lead time and the inventory level. Then, the results were inserted into the Minitab to generate main effect plot to analyze the factor main effect to the system. The effects of the control factors were calculated and the results were analyzed to select the optimum setting of the control factors. The outcome was to choose the best combination of factors and model. The best model was further evaluated in detail so that the solution meets the objective. If the simulation models showed the positive result, the process can proceed to the implementation stage for the best model. Vice versa, further analysis and modification to the Kanban model should be done.

The purpose of doing simulation is to evaluate the performance of the proposed solution before real implementation. The modification was done if the negative result was shown. This step is significant to reduce waste of resource, time, and energy and most important increase the possibility to success. The simulated result was used as a standard to compare with the result of real implementation.

3.6 Step 7: Design the Work Procedure, Information Flow, and Rules in Kanban System

The process flow of Kanban system was designed. The information needed was process lead time and the skill of the operators. The job scope of all people related and how the system run was designed in detail to ensure smooth flow. The time of the process should be balanced to minimize idle time.

The Kanban signal to trigger the production was also decided. The signal used can be a card, a cloth and so on. The procedure of information and material transfer were designed so that the operators clear about the steps during the Kanban replenishment.

Lastly, the rules are very important during the implementation of Kanban system so that the JIT production can be achieved. This is to ensure that the right material can be only be withdrawn at the right quantity at the right time. The rules were decided and trained to the operators so that the operators understand the rules during the Kanban implementation.

3.7 Step 8: Design Layout for Material Storage

The location and storage area of the Kanban material and other inventory were allocated carefully to ensure the efficiency and safety. The storage layout was drawn in Microsoft Visio.

3.8 Step 6: Modify the Kanban Model

The modification was done when the Simulation or pilot run showed negative results. This means that the proposed solution showed low capability to reduce the lead time and the inventory level. The modification and correction were based on the situation and simulation result. If the positive result was shown in simulation, the step can proceed to next process without doing any modification.

3.9 Step 9: Implementation of Kanban Model

In this process, the resource such as the labour, Kanban signal and grey bins (container of the inventory) were needed. Training and briefing were provided to operators prior to implementation to ensure clear understand about the process flow of Kanban system, their responsibility and task, rules, and the information flow in Kanban system. The submodules that were chosen to apply Kanban should be prepared according to the quantity determined in section 3.4.3. The implementation stage started from March’2017. Monitoring to the production was done as the early stage of implementation is very critical.

3.10 Step 10: Performance Measure & Monitoring

After the implementation, performance measure was done by measuring the lead time and the inventory level. The tools to measure the parameters are as Step 2: Time study was again used here to determine the time taken for each process.

Monitoring of the process was done for about 3 weeks to ensure the process is stable with the system implemented. If the performance measure did not show positive result, the cause of this problem should be identified and then proceed to Step 6: Modify the Kanban Model.

3.11 Step 9: Setting SOP

When the production was stabilized, the project was handed over to the process owner. SOP is Standard Operating Procedure which is systematic instruction to help the worker to carry out routine operations. The importance of setting SOP is due to efficiency, uniform performance, reduce error and ensure consistent result.

In this project, SOP was generated so that the staffs sustain the changes after the termination of this project. It ensures consistency in the production and prevents the production from falling back to initial condition. The information in the SOP contained information below: resource needed such as

- materials, equipment and labour
- process flow and working mechanism of Kanban system
- information flow and use of signal in Kanban system
- job specification of each operator
- rules of Kanban system

CHAPTER FOUR: RESULT AND DISCUSSION

4.0 Background of Case Study Company

The chosen company is a local company located at Penang Island. It is an automated vision inspection equipment manufacturer for semiconductor and electronics packaging industries. Their core products are Machine Vision system (MVS), Automated Board Inspection(ABI) and Electronics Communication System (ECS). Most of the machine produced in this company is by manual assembly. The volume of production varies for different products. The production chosen is also a low volume medium mix manual assembly production to manufacture an inspection machine for carrier tape inspection.

4.1 Phase 1 – Planning

a. Type of production and sequencing rule used

The production is manual assembly process. It is discrete production. The sequencing rule they are using is FIFO and Earliest Due Date (EDD). However, the priority of EDD is higher than FIFO.

b. Product Variety, production volume and demand

The product is medium degree customization as the structure is mainly standard. The customization is only for some submodule. Also, the demand of the product is considered low as the demand quantity is lower than 50 units every year. Thus, the production is considered as medium variety low volume. The production should have the capability to produce 6 units per month.

c. Manufacturing Process and the standard process lead time

The whole manufacturing process is as the process flow chart shown in Figure 4. 1. The project scope covered the processes from the sub-module assembly process to packing process. There are 7 sub-modules for the product. The process lead time of each process is shown inTable 4. 1. The lead time of each process is rounded to days due to the confidential issue. The roughly total standard manufacturing lead time is 11.2 days.

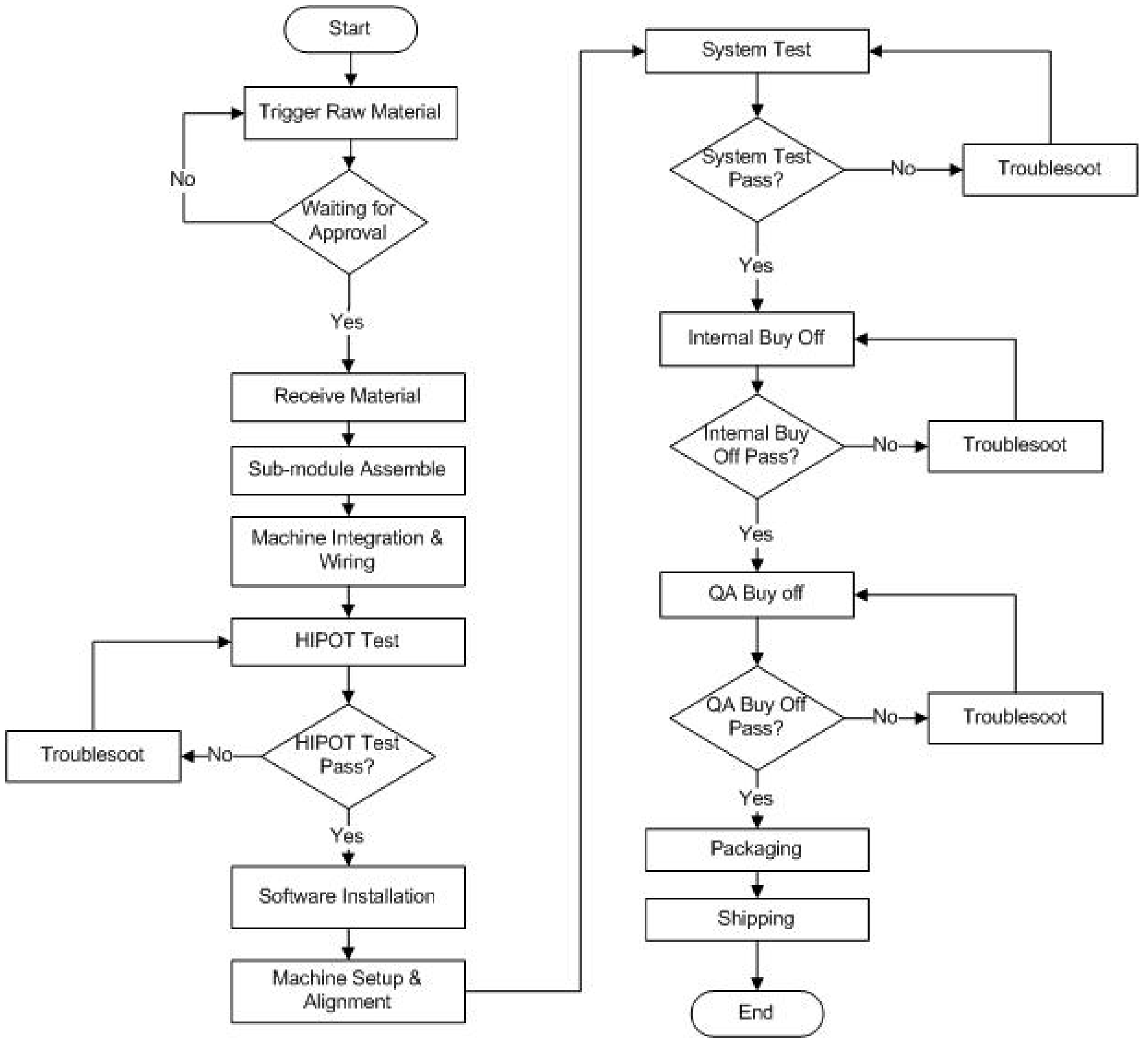

Figure 4. 1 Process Flow Chart