MATERIAL REPLENISHMENT SYSTEM FOR SMT KITTING

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DECLARATION

This paper is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Dr Chin Jeng Feng, at Universiti Sains Malaysia, Penang.

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ABSTRACT

Purpose – Surface Mounted Technology (SMT) requires hundreds of components in the electronics assembly process run in mass production. These components varying in sizes and costs have to be transferred from warehouse to an area for preparation, commonly known as kitting. Oversight in kitting leads to long material replenishment lead time, component lost, and overstocking at the kitting area. This case study aims to investigate the issue and to generate solutions in alignment of the lean manufacturing philosophies.

Design/methodology/approach – This case study is based on the SMT kitting area and warehouse of an electronic production plant. The project is executed by an undergraduate manufacturing engineering student and several operation leaders over a period of ten weeks. The methodology implemented is a plan-do-check-act (PDCA) approach. The data is collected via time study, direct observation and informal interviews.

Findings – A visual system was introduced to unveil delay at every stage of the material replenishment process between the SMT kitting area and the warehouse of the company.

Research limitations/implications – The case study is conducted in a discrete manufacturing industry where the sources and concerns may be localized and handled differently elsewhere.

Practical implications – A systematic approach is provided to practitioner to implement material replenishment system between the SMT kitting area and warehouse. The system promotes the replenishment lead time reduction, inventory reduction, SMT kitting area space expansion and waste elimination.

Originality/value – The paper is a real case study of electronics component replenishment between kitting area and warehouse. This field has not been explored to a high degree.

Keywords – Electronics assembly, PDCA, Lean Manufacturing, SMT, Kitting

INTRODUCTION

Surface Mounted Technology (SMT) is the process where electronic component, typically in hundreds are mounted on a printed circuit board (PCB). The size of component and the amount of the component in a reel varies. Changeover on SMT requires component reels to be changed in accordance to the order requirement. The process can be time-consuming and results in significant machine halt. As SMT is commonly the most expensive process in electronics assembly, the capacity utilization is always maintained at a relatively high level. Any machine halt will affect the productivity of the process. In recent years, kitting process is introduced so that offline preparation of real components on the detached raw material dock can be done to improve SMT changeover.

Kitting process is the first process in SMT. All operations in SMT are directly or indirectly affected by the kitting operation and schedule. Any discrepancy in the kitting process will hinder the operations in SMT to achieve continuous flow. The discrepancies include issuance of wrong amount of component, issuance of wrong component, and issuance of loose parts. Besides, it is very important for the material to be kitted on time at the right amount. The wrong amount or too early arrival of the material will increase the inventory in kitting area, which indirectly reduces the space availability. The late arrival of material will hinder the process to start on time, which consequently reduces the utilization of the machines and the productivity of the lines.

The ideal replenishment process is to replenish the component needed just-in-time (JIT). This can control the inventory at minimal safety stock and safety time. However, it is hard to immediately achieve JIT in real life. An electronic assembly plant was approached to study the obstacles towards continuous flow. Data are collected through a period of observations to understand the problem in extend. The material replenishment system is studied to find the root cause of the time problem.

In this case study, a reduction of Kanban operation lead time is documented. A Plan-Do-Check-Act (PDCA) approach is used in consideration of human factors as part of the framework. This paper is organized as follow: Section 3 introduces the study of material replenishment scenario in SMT and how is it connect via lean approach. Section 4 shows the PDCA methodology performed in this case study. Section 5 presents the case study in detail. Section 6 discusses the other issues related to the case study. Section 7 concludes the whole research.

LITERATURE REVIEW

Material Replenishment (Kitting, Milk run)

Kitting is a process where the individual materials are grouped, packaged, and supplied together as a unit. For SMT, reels of different components are gathered and set up on the feeder table. The feeder table feeds the component placement machine as a unit. Kitting operations include pulling the material list at the warehouse from the Material Requirement and Planning (MRP) system, and then the kit is audited at the warehouse itself. The completed kit is then shipped to the building, which houses the assembly line for that particular kit. At staging, the kit is audited by counting line items and then released to Surface Mount Technology (SMT) setup.

SMT kitting operation was observed with discrepancies such as: under issue of components, over issue of component, wrong part issued, loose parts issued, back order, and missing line items(Joshi et al. 2002). These discrepancies bring adverse effect of increased machine downtime, unnecessary hand loading, increase in work in progress (WIP), customer dissatisfaction, excess manpower needs. Any discrepancy will lead to poor line performance(Joshi et al. 2002). The untoward effects of instability in the kitting process are outlined below:

- Increased machine downtime;
- Increase in WIP;
- Customer dissatisfaction; and
- Excess manpower need.

Kitting error cost was relatively significant out of all the cost in material replenishment system(Caputo, Pelagagge, and Salini 2015).

Customer demands for good quality, cost, and delivery (QCD) (Amasaka 2014). The production control was challenged by the trend of multimodel, small batch production and low level inventory manufacturing. Material Replenishments Planning (MRP) and Just-In-Time (JIT) where two approaches developed to counter the challenges. MRP and JIT differs by lying on push and pull basis respectively (Gupta and Brennan 1993). Information transfer becomes a key factor of JIT to quickly response with solutions. This is crucial to sustain the continuous flow manufacturing systems without safety stocks and safety time. A conceptual framework is developed to link organizational problem-solving processes through the computing environment(Balakrishnan et al. 1995). The artificial intelligence strategy was introduced to construct a joint MRP/JIT production control system. The hybrid system is capable of analyzing implementation design strategies and observe the outcome even under influence of external factors (Gupta and Brennan 1993). Although JIT is in trend, its way of management is reassessed as part of the continuous improvement effort. New JIT structure involves more than just the manufacturing shop floor, extended to sales, design, R&D, engineering, and others. The integration of Total Development System, Total Production System, and Total Marketing System, covers most of the area and surpass the current JIT (Amasaka 2014).

Material replenishing for kitting is considered as supporting function to the production process. The function oversees regular material move from warehouse to kitting areas and vice-versa. These materials are in significantly different varieties and quantities. Information system has to be updated duly to accurately reflect on the stock level of raw material. These tasks are largely manual and affected by human factors. Communication is the first line of defence against both internal and external threats. An organization requires an adequate communication channel to pull through and face new challenged(Stroh et al. 2001). Communication includes encoding the intended meaning, the transmission of information, and the decoded meaning is perceived(Stroh et al. 2001). Noise appears throughout the communication process that affects the message perceived(Stroh et al. 2001).

Lean Manufacturing

Lean is a philosophy of no waste and several small improvements in long term(Carreira 2005). Lean production means doing more works with fewer resources and to achieve customers demand with satisfaction or exceed expectation(Groover 2008). Lean operation focuses on the customer needs and eliminates waste through continuous improvement(Heizer and Render 2013). Values is defined from the customer's advantage perspective(Carreira 2005).

Several lean tools relevant to the material replenishment for kitting are Kanban system, visual management, leader standard work and PDCA. They are reviewed as below:

Kanban is a Japanese word for 'card', which means 'signal'(Heizer and Render 2013). A Kanban system moves the inventory in small lot size through the supply chain with a signal that 'pulls'(Heizer and Render 2013). When the supply is used up, they send a signal to the upstream department or supplier to replenish. Signals are sent from downstream to upstream and thus create a pull where supply arrives when demanded. The signal does not requires two persons' contact, and able to control the specific quantity of parts. The size of Kanban card can be determined by the formula below:

$$\text{Size of kanban card } = \frac{Demand\ during\ lead\ time + Safety\ stock}{Number\ of\ kanban\ card}$$

Kanban can efficiently reduce the operation lead time, minimize the inventory of finish goods and WIP, and optimized the finished goods area(Naufal et al. 2012). Simulations are built to observe the behavior(Hao and Shen 2008) and to determine the optimal Kanban size (Chan 2001). A successful simulation can be a tool to assist business decision making. It visualizes the task completion capability out of various manipulating factor and the obstacle is shown. (Tregubov and Lane 2015).

Visual control is used to show if it is within or deviating the standard. It should be simple, informative, accurate and can be seen at the shop floor. Paper is preferred over digital screen as workers can be distracted from their work on hand(Liker 2003). The implementation of a visual control must be maintain for error detection function. A complementary tracking process and analysis should be developed to lead towards the root cause(Mann 2012). No problem can be hidden under visual management.

Leader Standard Work (LSW) is required to sustain the growth of a new standard. It involves Gemba walking, observing abnormalities, asking questions, and responding timely to the shopfloor. LSW should be documented and requires reinforcement to be followed(Mann 2012). LSW is known to solve problems permanently and able to grow the next generation of leaders through it. It fundamentally change the way of the leader's daily routine(Womack 2013).

Kaizen strategy highly rely on human effort to improve results and demand on process improvement(Walton 1988). PDCA also contributes in developing critical thinking. At Toyota, this is part of "Building people before building cars."(Liker 2003). Plan-Do-Check-Act (PDCA) cycle is a process-oriented approach. The ancestry of PDCA cycle or Deming cycle was found earliest in 1920s, Shewhart the statistician come out with the concept of plan, do, see. Later, Deming modified the Shewhart's cycle as: plan, do, check and act, a 4-steps improvement model(Basu 2004; Janakiraman and Gopal 2006; Kelada 1996). Plan-Do-Study-Act (PDSA) is further derived for the emphasis of analysis over inspection. Lean companies acknowledge that a committed, dynamic in problem-solving workforce, with the aid of PDCA, is more competent and innovative through rigorous problem solving and the subsequent innovations(Liker 2003). This creates a culture of problem solvers with critical thinking that use PDCA. Lean culture encourages the habit where all employees, at every level of organization, are problem solvers(Basu 2004). All employees are trained on problem solving techniques and coached to use them whenever they see an abnormal condition(Basu 2004). PDCA cycle is systematic, effective(Basu 2004), detail oriented and have general consensus (Janakiraman and Gopal 2006).

One of the most popular Root Cause Problem Solving (RCPS) tools in lean manufacturing is the 5-why analysis. Taiichi Ohno, the father of Toyota Production System was an avid proponent of the 5-whys analysis as a tool of root cause problem solving(Ohno 1988). The idea is simple. By asking the question “Why” one can separate the symptoms from the causes of a problem. This is critical as symptoms often mask the causes of problems. Effective use of the 5-why analysis technique will determine the root cause of any non-conformances and subsequently lead organizations to develop effective long-term corrective and possibly preventive actions.

RESEARCH METHODOLOGY

PDCA cycle of improvement can be defined briefly as follow:

- Plan – to understand the current situation and identify potential improvements with a prediction in the outcome.

- Do – to execute step by step under controlled situation.
- Check – to examine effect of changes to determine if the desired result is achieved.
- Action – to standardize the process with constant monitoring.

The primary objective of PDCA is to straighten from the abnormalities in the resulting work process and bring it back to harmony before moving to a new improving cycle. In other words, the standardizing cycle maintain current work processes, while the improving cycle improves them. Plan-Do-Check-Act (PDCA) is used as a problem solving method in business and production to control and continuously improve the processes and products. This logically structured problem solving method can be applied to almost all types of problems.

The PDCA flow chart shown in the Fig. 1 portraits this case study. The methodology used in this projects consist of 4 stages with a number of sub-stages respectively. These steps are selected in considerations of the nature of the project and the duration permitted for the project. In accordance to the company culture, a team is formed to conduct the project. The team includes: operation manager, area manager, team leader, acting leaders and operators. During the team formation, a long term challenge is defined to help the team focus on the True North direction. The data is collected via time study and interviews conducted with several operators. New standardized work plan and leaders standards work are generated. The framework of each stages is explained next.

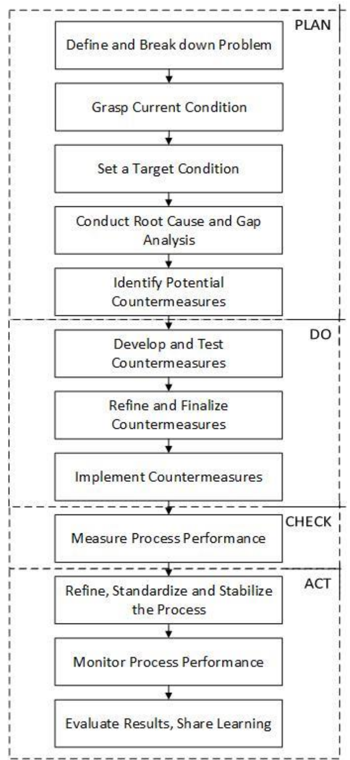


Figure 1 PDCA Methodology Flow Chart

Plan Stage

The problem is defined in accordance to the current situation or pain point. This includes a description of the process and what is wrong. The problem should be specified enough to show the example and why the project is executed without biasness and blame. It is further breakdown to identify the impact of the problem towards the process and the company. The scope should not be too narrow nor too broad. A team is formed in accordance to the implicated department from the project.

The current condition is grasped via detail observation at the G*emba* (the place where the problem occurs). It is important to go to the source and personally observe and verify the data rather than theorizing on the basis of what other people or the computer screen tell you (Liker 2003). The quantitative data current condition can be collected through various tool such as time study, work sampling and standard data. It is illustrated with photo, graphics, charts, descriptive statements, process flow and other expressible tool. Apart of the physical situation, the attitude how a person treat their work should be observed. This is because manual operation is fairly subjective to the individual. The performance at a time will not be the performance at all time. The reason why different level of conformity to the standard present should be identified and considered. Interviews can be done to obtain qualitative data. It is important to understand the right problem thoroughly more than the surface symptom of the true problem.

The target condition is set to be achievable within the permitted project period and described the favored pattern of operating to reach at the future point of time along the way towards the longer-term challenge. The aspects in target condition should be measurable to tell if it is reached or not. A goal is set specifically relevant to achieve and measure the improvement within the project time bound. The target condition is a description of the team direction instead of the procedure to achieve it. The obstacles are determined to adjust or accommodate along the project.

Root cause analysis is conducted to ascertain the mixture of factors contributing to the problem and prioritize them. Rectifying the right cause will practically solve the matter with the least investment-to-impact ratio. The causes can be categorized as constant factor, noise factor and experimental factor. The causes identified is best to be avoided from preconceived idea. Gemba walk is necessary to identify the cause and not fully depend on the others data. Questioning, discussion, brainstorming and counter check the situation are needed to not lose any detail in the problem. The effort shall not end until all root causes are discovered. The tools to conduct root cause analysis are graphical and numerical analysis, Ishikawa fishbone diagram, 5-why analysis.

From the decided causes, the potential countermeasures are identified. The problem may contain multiple root causes. There is more than one way to solve a problem and a low tech solution probably exists. These countermeasures are identified regardless the hindrances later.

Do Stage

All the potential countermeasures are thoroughly considered. This stage known as *Nemawashi* involves discussing problems and potential solutions with all those affected, to collect their ideas and to get agreement on a path forward (Liker 2003). The solution that yields the optimum respond is often prioritized. The results are tested and adjust to overcome or accommodate the obstacles. It can be done through simulation of the process to consider if a solution is possible by time, cost, and complexity to practice. The team shall discuss the solutions based on their knowledge and experience. The most common pitfall is to implement everything without proper evaluation with data support. Multi-voting is suitable to narrow down the scope. Prioritization matrix can be used to analyze the potential countermeasures by different decision criteria according to a weighted average.

The countermeasures is then refined and finalized. Documentation is done and the process owner is identified and assigned with respective key performance index (KPI). Training material is prepared if necessary. This will contribute to the measurement of success of the project. The people who work in the process is communicated about the changes.

The decision is made slowly by consensus and implement rapidly. Training is given to related stakeholders if necessary. Short term and long term countermeasure can be coordinated and monitored using a Gantt chart. The long term countermeasure can be broken down to small increments and its progress checkpoint is defined.

Check Stage

The performance of the project is observed and tabulated charts. This stage allows us to compare the results from the goal. The process owners monitors the improvement and leads the ongoing improvement as needed. The secondary benefits from the improvement are identified. A financial benefit can be calculated from the improvement achieved.

The reflection on the effort is done. The appropriateness of the process and tools, the collaboration within the team, the knowledge gained from the involvement and the future work are considered. Visual management tool, run charts and statistical Process control can be used in this stage.

Act Stage

The improvement is refined, standardized and stabilized. It is expected to be sustained. Therefore, standards for the new processes are established. Ownership of each process must be clearly stated to ensure the standards are in place and sustaining the gain.

The process performance is under continuous monitoring. Poor planning, execution, and process management will lead to failure. Visual management is set by the team for the group to see, act and know the same information. The leader standard work (LSW) of each relevant sector is set to raise human commitment in ensuring that the new standard is being followed in the production process. LSW can be presented in different forms and formats: email, notes, Gemba walk review etc. It is the responsibilities of leaders in lean production environment to ensure processes run as designed and the improvement is sustained.

The improvement methodology is shared to the other department or plant where applicable. The project is closed off by setting a new target condition of the next step. Before the dissolution of the team, the modified job scope are properly handed over to the process owner to maintain the improved performance.

CASE STUDY

Introduction of company

Established in northern part of Malaysia, Company X produces sound system products. The production department consists of transducer production, Surface Mounting Technology (SMT), Through Hole Technology (THT), Noise Reduction Technology (NRT) and Final Assembly (FA). Their products include earphones, speaker, automotive sound system, home entertainment sound device, and so on, are supplied globally. The plant operates two shifts a day, six days per week (overtime on Sunday if backlog occurs), and has more than 1000 employees.

PDCA steps

Plan Stage

Kanban is a signal from kitting area to the warehouse to notify for material replenishment. In the company, the Kanban signal is a card contains the material part number and its quantity. The Kanban operation lead time is clocked from the moment it is drop to warehouse until the material is replenished on the waiting rack in the SMT kitting area. The Kanban operation constitutes of four major stakeholders: kitting area operator, data entry, picker, line feeder. There are three types of Kanbans in SMT kitting area: high value component (HVC), low value component (LVC) and printed circuit board (PCB).

The case study is conducted during the peak season of the production. LVC and PCB are fast moving material. HVC, LVC and PCB are equally important in SMT process, lack of either one will cause the SMT line to stop. The company suggested us to focus on HVC to study the material replenishment flow.

The material replenishment system is observed thoroughly. All the internal stakeholder of HVC is identified. A team is formed to solve the problem met in material replenishment. This team includes leaders from SMT, SMT kitting area, warehouse electric team and the security. For a deeper understanding, the team went on several Gemba walks and conduct interviews informally.

In the SMT kitting area, the HVC is in charged by a specific operator for each shift. This specific operator also in charge the Kanban operation of PCB. Her job scope involves receiving and the issuance of HVC and PCB in the kitting area, and her priority is given to the issuance of material to SMT line. The partial reels returned from SMT lines are stored in the kitting area and will be used first when the line demands for it in future. The SAP system in the company does not provide a transaction interface between the kitting area and line, therefore an Excel Macro is built for all HVC transactions. The receiving process of all materials in the SMT kitting area may delay by errors such as wrong material delivered and incorrect data on the material identity (MID) label. As the production schedule differs every day, not all Kanban needs to be fully replenished. The unused Kanban was kept in a box. When a HVC is in demand, the operator will look through the box for that Kanban card and send it to the warehouse.

In the warehouse, all HVC are stored in the high value cage. There are two pickers in a shift for high value cage who pick the material needed according to the picking list generated by the data entry. These data entry personnel are also in charge of data entry for HVC from other lines and all Kanban from SMT. The pickers are also in charge of receiving HVC from the other operation departments and put them onto the rack. In the warehouse, HVC is defined as a component that can be applied widely, which requires tighter security. Apart from those, the warehouse also classified the subassembly of a final product as HVC. The picker's priority is on issuance and receiving of FA which indirectly cause delay in the SMT Kanban operation. All entries and exits at the high value cage are verified by a security officer. The line feeder for SMT HVC is part of the job of the data entry. All completed stages are signed by the person in charge with a timestamp at the picking list.

Fig.2 illustrates the material flow of HVC from the buyer till it is loaded onto the machines as printed circuit board assembly (PCBA). The initial practice of HVC replenishment is based on just-in-time (JIT) concept: Kanban is sent to the warehouse at expected Kanban operation lead time prior to the demand of the line. The kitting area operator will gather the Kanban of HVC needed and send to the data entry area of the warehouse. Picking list is generated to ease the picker in getting material. The picking list is also the documentation of each batch of Kanban received.

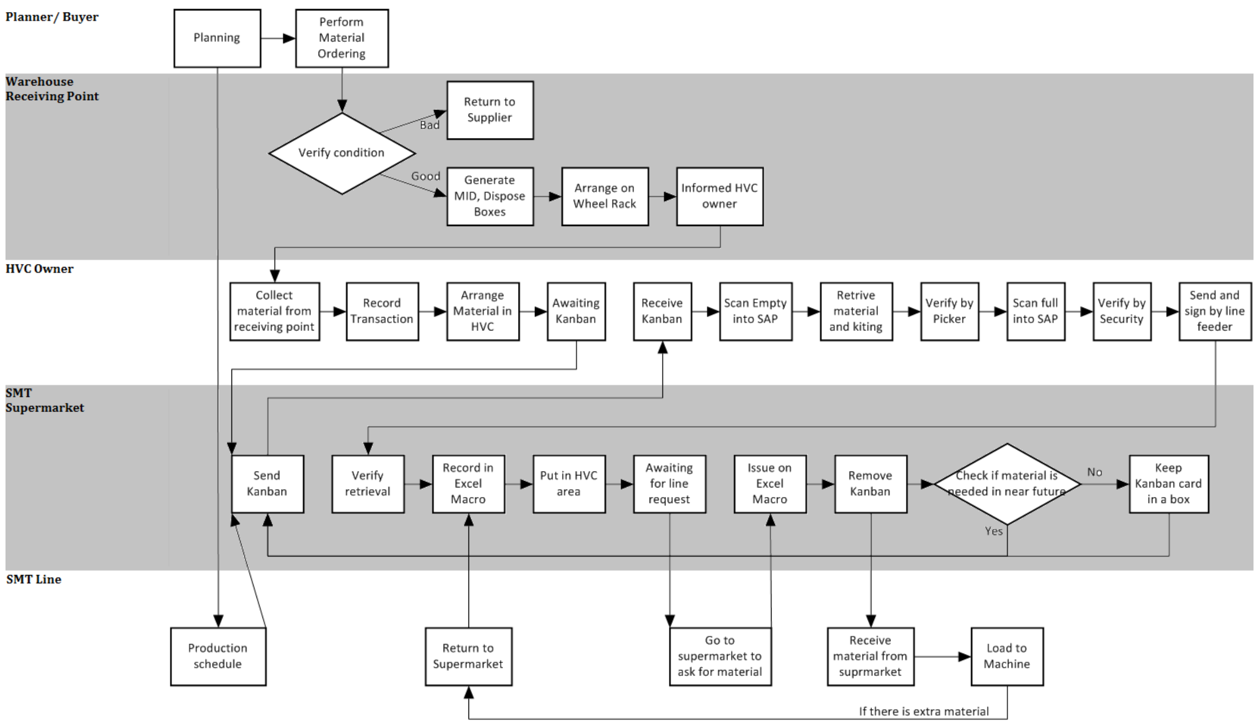


Figure 2 Process flow of high value component (HVC) in SMT

From Fig. 2, the flow of HVC between SMT kitting area and warehouse are as follow:

1. SMT kitting area found a HVC is in demand, thus HVC operator will look for the HVC Kanban card from the box it is kept.
2. The Kanban card is brought to the warehouse by the HVC operator.
3. The barcode on Kanban cards is scanned by the warehouse data entry personnel to inform the system that this card is empty and need to replenish.
4. A data list of the scanned Kanban is generated by the system. The data is copied and pasted on the spreadsheet template of the picking list.
5. 3 copies of picking list are printed and sent into the high value cage with the Kanban cards on top of it.

6. The picker took the picking list and look for the materials to replenish. The material picked are placed on a trolley.
7. After all material on the list is picked, the Kanban card is attached on the material and its barcode is scanned to inform the system that these materials are replenished.
8. The picking list is signed by the picker with time and the picking list is left on the cart with the materials.
9. The material on the trolley is verified by the security guard at the high value cage and the picking list is signed. A copy of the picking list is kept by the security.
10. HVC is delivered to the SMT kitting area by the line feeder, i.e. the data entry personnel, and hand over to the HVC operator.
11. The HVC is verified and received by the HVC operator. A copy of the picking list belongs to SMT and the last copy is returned to the line feeder right after the verification process for warehouse documentation.

The warehouse electronic team was informed to treat HVC Kanban from SMT as top importance and given full priority upon other Kanban. If the order given is followed, the 11 steps process above should take much lesser time than 6 hours.

Time study is conducted on the Kanban operation. The Kanban operation lead time for the material replenishment in the SMT kitting area can be broken down as follow:

a) Time to look for Kanban cards
b) Time to process Kanban in warehouse
c) Time to receive a batch of Kanban in SMT kitting area

In eight samples, the time needed to look for Kanban to send to warehouse is in average of 7mins with a deviation of +12mins or -4mins (Fig. 3). The Kanban card takes an average of 5 hours to process Kanban in warehouse with a deviation of +3.15 hours or -3.6 hours (Fig. 4). The receiving process at supermarket is in average of 54 minutes with a deviation of +58mins or -49mins (Fig. 5). In total, the average HVC Kanban operation lead time is 6 hours.

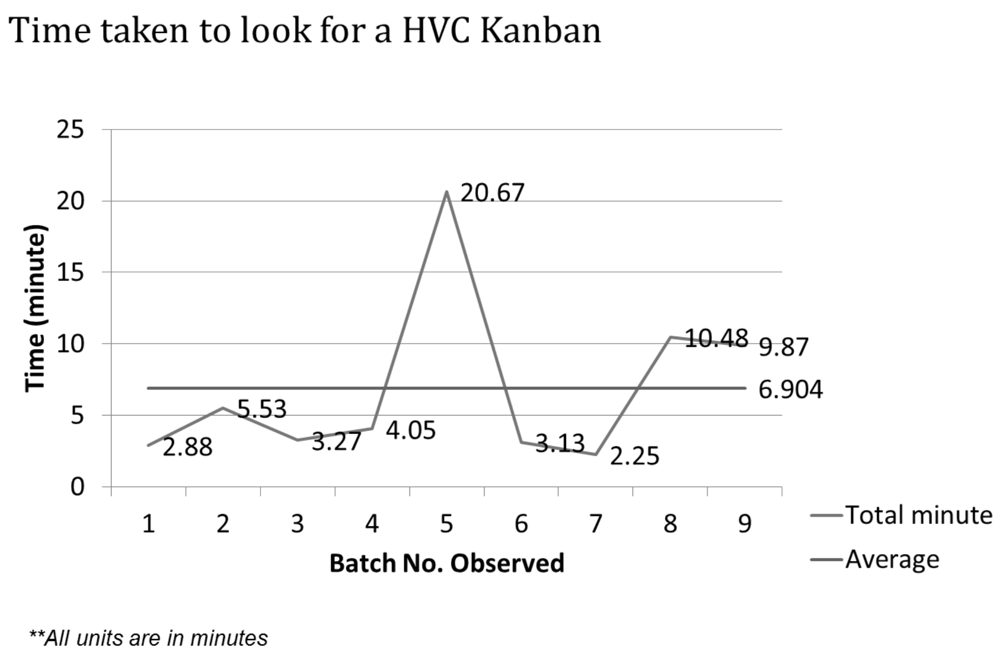
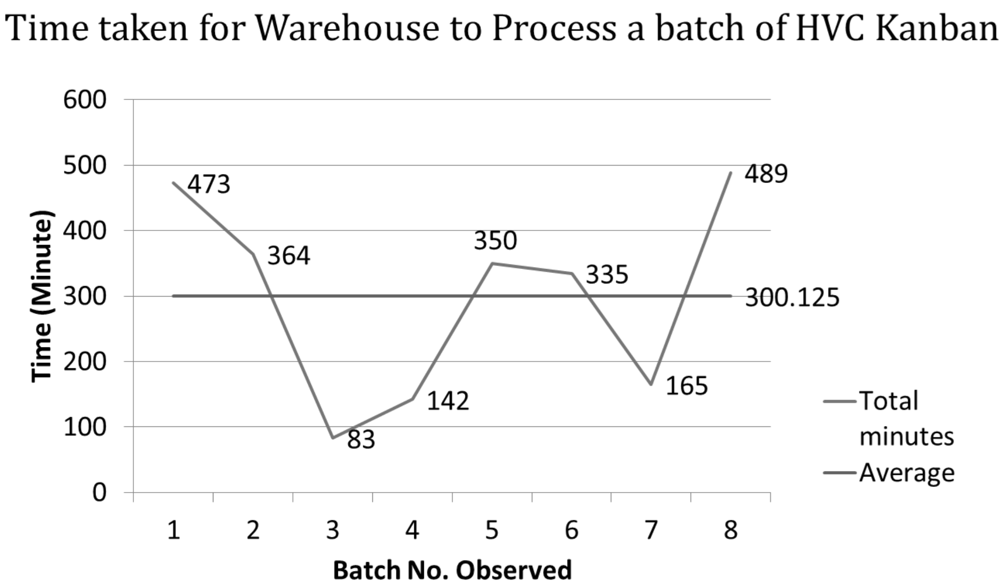
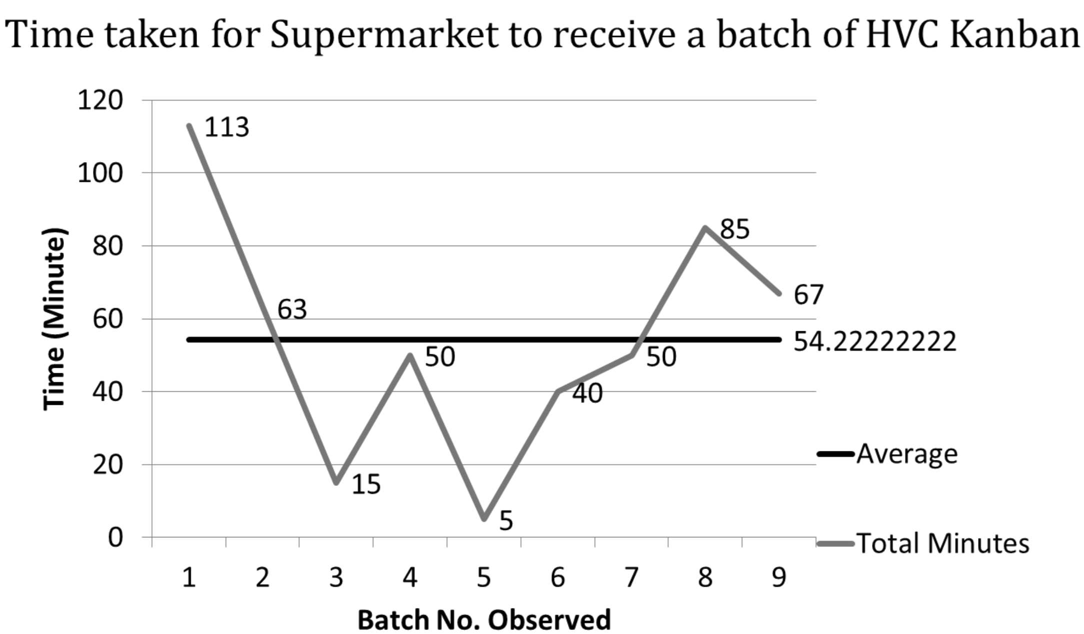


Figure 3 Time taken to look for Kanban from the box



***Number of kanban varies from 1 to 89*

Figure 4 Time taken of Kanban operation in warehouse



***Number of kanban varies from 1 to 89*

Figure 5 Time taken for Kanban receiving in SMT kitting area

The long lead time needed for kitting in SMT initiates the Kanban to be sent to warehouse earlier. The high fluctuation of lead time for kitting urges the Kanban to be sent in big amount to avoid the production line being starved. For example, HVC operator thinks the warehouse will replenish in a very slow rate, therefore she sends in the Kanban for HVC needed for the next 24 hours. This built up the inventory at the supermarket area and hence reduced the kitting space. After a few times HVC for SMT was replenished at the warehouse electric team's own pace and nothing happens, they learn that the urgency of HVC in SMT is not as high as informed.

The Kanban operation lead time is broken down by the activity in percentage (Fig. 6). Out of 6 hours, 2% of the time is used to look for Kanban from the box, 15% time is used in the receiving process, and 83% of the time is used in the warehouse. This leads us to focus on the activity in the warehouse.

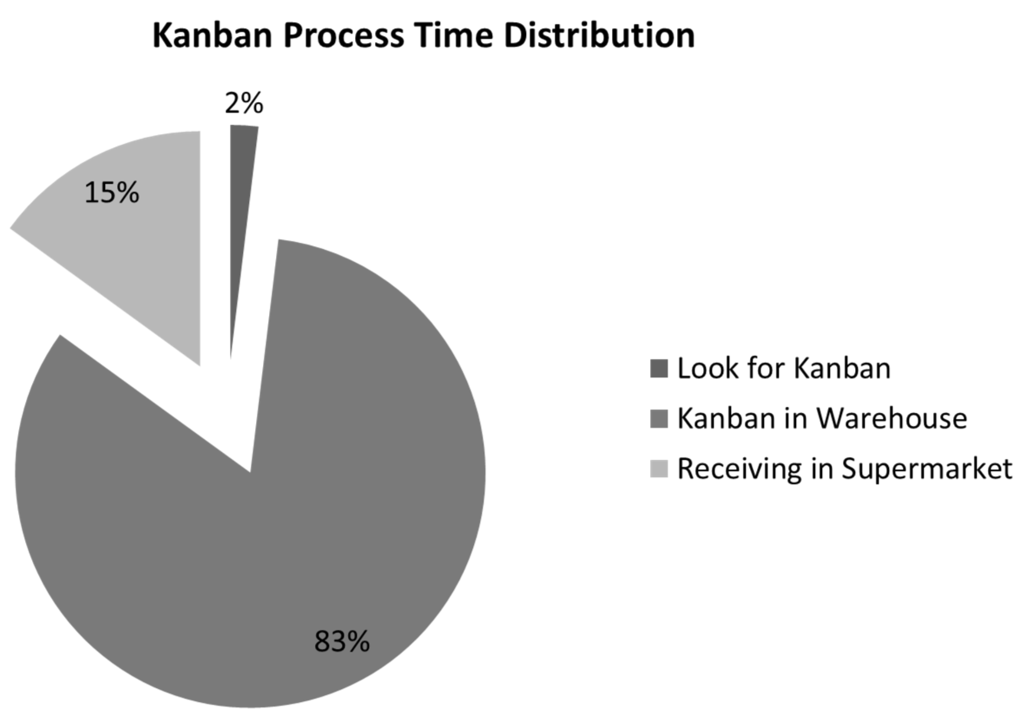


Figure 6 Kanban operation lead time breakdown by activity