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RESEARCH ARTICLE

OVERCOMING MATERIAL OVERFLOW USING FLEXIBLE LOT SIZE FOR KANBAN SYSTEM

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ABSTRACT

The aim of this paper is to propose the Flexible Lot Size (FLS) for Kanban System as solution for incoming material overflow problem at Compound/Kitting section in the hard disc assembly company. The FLS is used to synchronise the material flows between Warehouse and Module section (hard disc assembly lines) where the Compound/Kitting section is the intermediate station for the incoming materials supplied by the Warehouse. Value Stream Mapping (VSM) tool was applied to identify the nature of incoming material overflow at Compound/Kitting section and its implication to the performance of the subsequent production process. The daily changes of demand pattern were analysed based on three categories of demand volume; (i) low demand, (ii) medium demand, and (iii) high demand. The model of FLS is developed using Pro-Model based on current production system and Kanban system. The FLS is proposed based on the optimisation results through the three categories of demand volume. This paper proves that VSM tool is an effective tool for mapping production wastes in current production system. For the case of demand uncertainty, the FLS for Kanban system can be used to generate the optimum number of Kanban and lot size. Thus, the FLS for Kanban system can provide smooth production flow between Warehouse, Compound/Kitting section and Assembly line section which are the common sections in the hard disc assembly company. In short, the proposed FLS for Kanban system is capable to minimize the overflow of incoming materials at Compound/Kitting section.

INTRODUCTION

Most of the times, manufacturing companies, particularly the assembly process facing common operations problems that affect the productivity such as queuing, waiting, high production wastes, high inventory, over production, low utilization, and etc. In the meantime, the manufacturing companies have to solve the problems continuously in order to survive in the competitive market. According to Sukri (2007), these problems can be addressed by performing some analysis to their current manufacturing approaches. His study proves that Lean Manufacturing (LM) practice is as an effective method for the improvement of continuous productivity. LM provides numbers of tools and techniques to reduce the seven production wastes; (i) overproduction, (ii) inventory, (iii) transportation, (iv) waiting, (v) unnecessary motion, (vi) inappropriate processing, and (vii) product defects (Womack *et al*., 1996). Singh *et al*. (2010) discover that the manufacturing company becomes highly responsive to customer demand while producing quality products in the most efficient and economical manner. Shah and Ward (2003) found that the influence of lean practices contributes substantially to the operating performance of plants. However, the implementation requires customized solutions. This is because the internal materials flow to and from each workstation depends on the production conditions and particular characteristics of the workplace. Value Stream Mapping (VSM) is one of LM tools that has emerged as the preferred way to support and implement the lean approach (Grewal, 2008). VSM is a tool used to identify where the wastes occur and the sources of wastes as well. For example, an application of VSM can be found in redesigning assembly line in the valve production process (Álvarez *et al*., 2008). In their research, VSM can be used to redesign the assembly process by

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eliminating non value added time and decreasing the intermediate stocks. Kanban system is one of LM techniques that also known as Pull system. The essence of Kanban concept is that a supplier or the warehouse should only deliver materials to the production line as and when they are needed, so that there is no inventory in the production area. The word Kanban itself represents its operating mechanism. In Japanese word, "Kan" means card and "Ban" means signal. Thus, signal with card has been used to control the material flows along the production lines. In order to ensure the implementation of Kanban system a success, certain factors should be considered such as inventory management, vendor and supplier participation, quality improvements and quality control and employee and top management commitment (Kumar, 2010).

Lai *et al*. (2003) claimed than Kanban card has been used to identify problems of production flow, maintaining the synchronization of inventory and material flow among the production lines. Within this system, workstation located along the production lines only produce/deliver desired materials when they receive a card, indicating that more parts will be needed in production. Gupta *et al*. (1999) stated that the early Kanban system was designed for a deterministic environment (e.g. stable demand and constant processing times), its performance is optimum in the environment. However, once implemented, Kanban system is fraught with numerous types of uncertainties such as processing time, demand variation, machine breakdown, and other types of planned or unplanned interruptions. Hence, some degree of flexibility is necessary to cope with the uncertainties, and this might include a variable number of Kanban (Domingo *et al*., 2007).

According to Sundar *et al*. (2014), during demand uncertainty the buffer maintenance is necessary for smoothening production flow and reconfigures the Kanban System in order to lower the inventory. In this case, the Kanban system provides mixed model production along with optimal inventory level which results in less lead time in product delivery and effective utilization of resources such as man, machine etc. Earlier, a technique called "Flexible Kanban System" (FKS) was introduced in the production environment to compensate for discrepancies introduced by unpredictability (Gupta and Al-Turki, 1997; Gupta and Al-Turki, 1998; Gupta *et al*., 1999). The FKS fluctuates in the number of Kanban during the production cycle.

However, optimisation issues in demand uncertainty have continuously searched for the best solution. Therefore, this study adopts the concept of FKS in developing Flexible Lot Size (FLS) to overcome the problem of incoming material overflow at Compound/Kitting section in the hard disc assembly company. There are two objectives need to be achieved in order to develop the FLS for Kanban system at Module section. The first objective is to identify the nature of incoming material overflow at Compound/Kitting section and its implication to the performance of the subsequent production process. The second objective is to analyse the pattern of daily demand volume changes patterns and its effect to the Compound/Kitting section and Module section performances. This paper consists of five sections including introduction section. Section 2 shows the view of the incoming material overflow problem at the hard disc assembly company. Section 3 explains the detail stages of research methodology in order to achieved all objectives and meet the aim of the study which is to solve the overflow of incoming materials problem using FLS adopted from the concept of FKS. Section 4 presents the results and discusses the findings of each stage. Section 5 concludes the research findings, research limitations, and proposes extended research.

Overview of the company problem

For hard disc assembly process, Compound/Kitting is the first step that involves gathering all parts needed for a particular assembly line. In this regard, Compound/Kitting section performs as an intermediate storage that collects the materials supplied directly from Warehouse and issues the materials to the next Assembly lines section. The main problem faced by the company is the Compound/Kitting section always crowded with high incoming materials, even though the materials are pulled out almost every hour. One of the factors that contribute to this problem is the uncertain changes in planned demand quantity. Figure 1 presents the flow of material and information among supplier, Warehouse, Compound/Kitting section and Assembly line section.

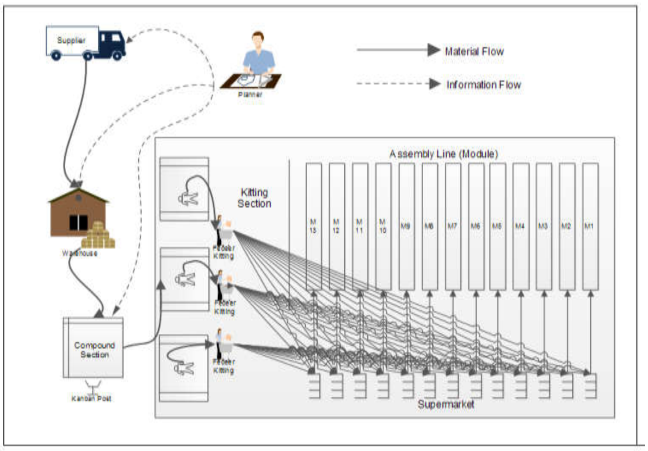

Fig. 1. The flow of material and information among supplier, Warehouse, Compound/Kitting section and Assembly line section

More than 50 different components are delivered from the suppliers and arrive at the factory by truck. The components are loaded to the warehouse area. From the Warehouse, trolleys will be prepared to accommodate the components according to the schedule from production planner and the components will be delivered to the Compound section. The empty trolleys in the Compound section will be brought back to the Warehouse and refilled to the next delivery. Here, the push system has been applied between Warehouse and Compound section. In the current system, the components in the Compound section are stored in the trolleys. When all the trolleys are full, the floor space near Compound section is used as the intermediate storage for the excess materials from the Warehouse. From the Compound section, components will be sent to Kitting section by receiving the pulling signal from the feeder kitting which later the components will be sent to supermarket racks. In this context, supermarket racks serve as the store of components required by the final assembly line. According to Emde and Boysen (2012), decentralized supermarkets enable frequent small lot deliveries of parts, so that inventory at the line is reduced and long-distance deliveries from the central receiving store are avoided.

MATERIALS AND METHODS

This methodology consists of three phases: *(i) development of Value Stream Mapping, (ii) identifying the demand pattern,* and *(iii) development of Flexible Lot Size for Kanban system.* It focuses on T product family which present the highest demand of the company. In this regard, three components of T product family; those are MBA, MEDIA and HAS have been studied.

Development of Value Stream Mapping

Information on the current production process such as material and information flow, planned demand quantity, inventory level, working hours, number of operators, cycle time, and transfer time are gathered to develop the VSM. (Nandikolmath *et al*., 2012) described VSM as a visual tool that integrates material flow and information flow into a critical path chart to understand the relationships and the importance of all VA and NVA actions.

In this study, the current state VSM represent the visual depiction of how the existing process works in Warehouse, Compound/Kitting section, and Assembly line section. This study used both qualitative and quantitative data. Qualitative data was gathered through the observation and interviews which were conducted with superintendent, supervisor, and operators who were familiar with Compound/Kitting section. The qualitative data consists of the review of work methods such as flow of material and information. Meanwhile, the quantitative data were collected through archival sources, such as three months data of production output quantity per shift, also historical data on the planned demand quantity. For the data analysis, activities such as selecting the specific product family to be mapped; review of material and information flow; establishment of standard cycle time and determination of production performances were carried out. This activity becomes the prerequisite to the development of the VSM.

The result of data analysis then used to visualize the entire production process using current state VSM. The main objective of current state VSM is to provide an understanding of current Compound/Kitting production flow in terms of demand quantity, system layout, production wastes, also a visual flow of material, as well as information flow. At this point, the root-causes of the incoming materials overflow could be identified. The steps in developing the current state VSM adopted from (Rother and Shook, 1999) as follows:

- Draw customer, supplier, and production control icon
- Enter customer requirement (demand) per month and per day
- Calculate daily production and container requirements
- Draw inbound shipping icon, truck and delivery frequency
- Add process boxes in sequence from left to right
- Add data boxes
- Add communications arrows and noted method and frequency
- Obtain process attributes and add to data boxes
- Add operators symbol and numbers
- Add inventory locations and levels in days of demand and graphs at the bottom
- Add push, pull and FIFO icons
- Add working hours
- Add cycle and lead time
- Calculate total cycle time and lead time

By having the current state map, it is critically analysed to improve the production system. Hence, the overflow of incoming materials can be minimized. Drawing the future state map is the last step in VSM, which is the result of the analysis toward the current state map, steered by the lean principles. Singh *et al*., (2010) explained that the future state map is a drawing of an ideal state which is the best way the process could operate starting from the current state analysis. In addition, Future state VSM is a picture of how the system should look after the inefficiencies in the current state map have been removed. In general, the future state VSM is developed using the following guidelines:

- The takt time was produced for T family product
- The continuous flow was developed where-ever it was possible and required
- Replace push by pull system

Identifying the demand pattern

The demand pattern was identified through the historical data of the planned demand quantity. It is the demand quantity which is released by the production planner to the production shop floor through the production plan system. In this study, the planned demand quantity is classified into three category of demand volume; (i) low demand, (ii) medium demand, and (iii) high demand that derived from the frequency distribution method. In this method, the class width is calculated using the following equation (Triola, 2008):

$$Class\ width = \frac{(maximum\ value) - (minimum\ value)}{number\ of\ clasess}$$

By classifying the planned demand quantity, the pattern of demand changes within three category of demand volume can be studied. In the meantime, the gaps between planned demand quantity and production output quantity is calculated to study the discrepancy of the production plan and actual production output. Hence, the effects of demand changes pattern to the production performances (e.g. inventory level at Compound/ Kitting section) can be identified.

Development of Flexible Lot Size for Kanban System

FLS for Kanban system is proposed using simulation model. In this study, ProModel version 7.5 has been used as the simulation software. Figure 2 presents the inputs and output variable used to build the simulation model of the current production system. The input data consists of system configuration and system attributes. The system configuration is composed of the current information and material flows also the locations that describe in the current state VSM. Apart from this, planned demand quantity data, processing time, material lot size, material transfer time and number of operators are also utilized as the system attributes data in the simulation model. In order to convince that the current production system simulation model has represented the real system, verification and validation should be carried out. In this case, the verification method used is tracing technique through audit trails, screen messages, and graphic animation (Harrell *et al*., 2004).

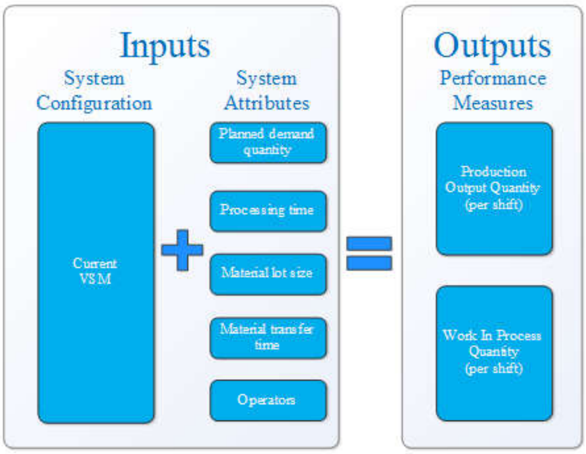

Fig 2. Inputs and Outputs Variable of Current Production Simulation Model

The verification was reconfirmed by the production engineer of the company in terms of material and information flow. Furthermore, the validation was done by comparing the data of production output quantity generated by the simulation model of the current production system with the actual quantity of production output data. In this regards, the Normality test and one sample T test done by using Minitab Statistical software. The verification and validation ensure that the simulation model of the current production system performs as how the real system operates. The result of current production system simulation model was used as the basis to construct the Kanban system which is depicted in future state VSM. Based on the future VSM, the material distribution system from the Warehouse to Compound/Kitting section which currently using Push system is replaced by the Pull system specifically Kanban system.

The Pull system enables the production based on customer demand; the downstream process takes the product they need and 'pulls' it from the producer. (Sundar *et al*., 2014) stated the successful pull system depends on flowing product in small batches (approaching one piece flow where possible), pacing the processes to takt time (to stop overproduction), and signalling replenishment via a Kanban signal. In this study, the Kanban system operates as a single-card Kanban system. The single Kanban system is applied to the simulation model of the current production system that has been verified and validated with the real system. In this case, the single Kanban system can be described as follows:

- The system consists of parallel assembly lines. Since the assembly line has already adopted the one piece flow system, each assembly line is represented by one machine location.
- T family product type is produced in the system. All the materials (MBA, MEDIA, HAS) must be processed on the assembly line.
- The flow of materials comes from the Warehouse till and each material is withdrawn by its succeeding section follow the standard lot size.
- The flow of materials right through the product line is controlled by Kanban cards, which means there is a number of Kanban cards associated with each type of materials at each section.
- The distance between the Warehouse and the Assembly section is separate into different floor. Thus, Compound/Kitting section and supermarket rack are made available between the sections.

Furthermore, based on the analysis of demand pattern, the experiments are then conducted toward the Kanban system simulation model to propose the FLS Kanban System. In this regard, five experiments were designed according to demand changes pattern. Then, optimization process was done in each experiment to determine the optimum lot size and Kanban number correspond to the demand changes. In this study, SimRunner software was applied for the simulation optimization. The SimRunner optimization software is an add-on capability for ProModel simulation software. According to Srisuwanrat *et al*., (2008), SimRunner turns the simulation model into an answering machine by the best answer possible while saving the most time. The optimization process takes an existing ProModel simulation model and performs sophisticated "what-if" analysis and optimization automatically. SimRunner uses both genetic and evolution strategies algorithm with its primary algorithm being evolution strategies (ProModel Corporation, 2002). In this regard, an evolutionary strategy algorithm is a numerical optimization technique based on simulated evolution.

According to (Thomas *et al*., 1997), evolutionary strategy algorithm mimics the process of natural evolution, the driving process for the emergence of complex and well-adapted organic structures. Solution generated from the evolutionary algorithm must adapt to their environment in order to survive. Since each potential solution returns a specific result, an objective function needs to be established to measure the performance of each solution. In this study, the objective function is determined as:

$$Z = [\text{Min}(2*\text{Inventory}_{MBA}+2*\text{Inventory}_{MEDIA} + 2*\text{Inventory}_{HAS})] + [\text{Max}(\text{Throughput}_{HDA})]$$

Here, inventory refers to the inventory average quantity of materials (MBA, MEDIA, HAS) that is kept in Compound/Kitting section. While, throughput refers to the HDA output that is produced by the assembly line to fulfil the demand.

RESULTS AND DISCUSSION

Value Stream Mapping (VSM)

In this study, current state VSM has been used as a tool to analyse the current production system status. Hence, the nature of incoming material overflow at Compound/Kitting section and its implication to the performance of the subsequent production process can be identified. In addition, the future state VSM is developed in order to visualize the future production system after eliminating the waste by applying the LM tools (i.e. Kanban system). Figure 3 presents the current VSM that have been developed. It can be seen that the focal point of all information collection and dissemination occurs in the planning department. Quarterly demand is taken from the market and processed by the planner that present as the planned demand schedule per shift, daily, weekly, and monthly schedule.

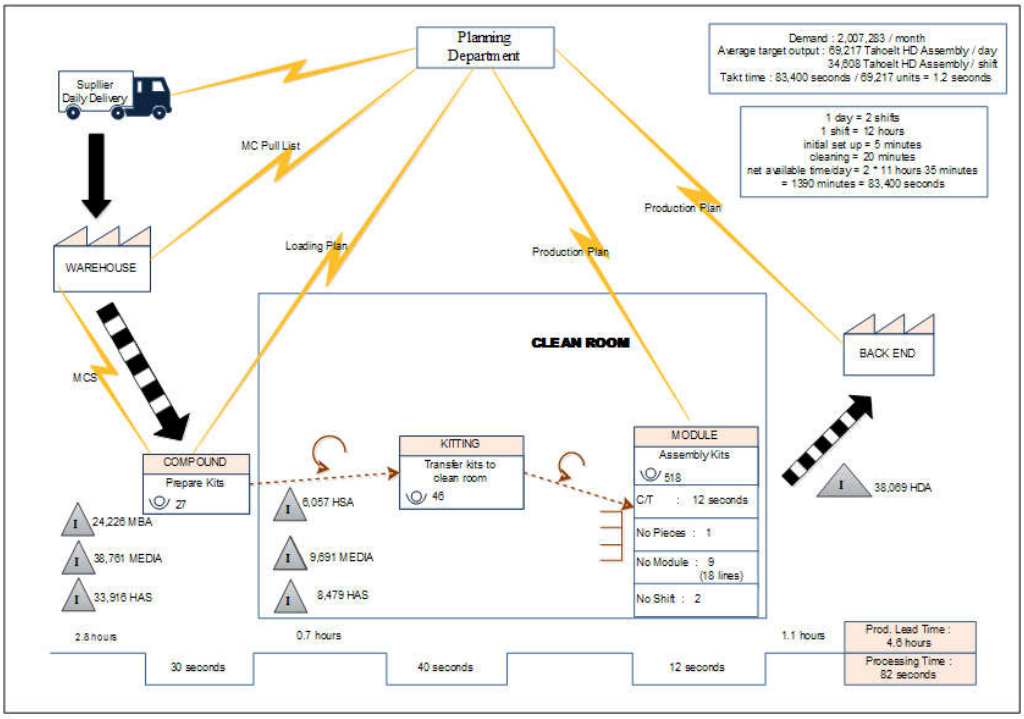

Fig. 3. Current State Value Stream Mapping

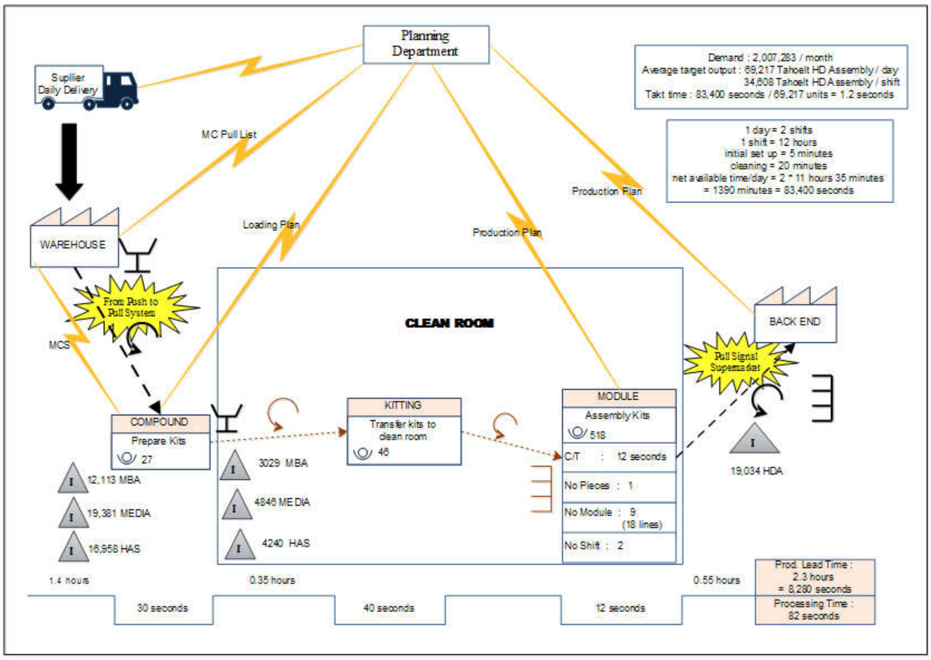

Fig. 4. Future State Value Stream Mapping

The planner distributes the schedule to the shop floor, so that the shop floor can know how many products that they should produce in the period of time. By using Material Control (MC) pull list, the planner lets the supplier know about how much raw material needs to be delivered to the Warehouse. The loading plan is issued by the planner to the Warehouse and Compound/Kitting section. It contains information about how many materials that should be sent from the Warehouse to Compound/Kitting section. The information is then used as input data to the Material Control System (MCS). MCS regulates the material distribution from the Warehouse to Compound/Kitting section.

In the current system, the Warehouse sending the raw material to the Compound/Kitting section in almost every hour decided by MCS. However, this is done by a push system. Meanwhile, the Compound/Kitting section serves for the pull signal from the feeder in the Assembly line section. In this regard, problems happen as there is a deficiency in the push system from the Warehouse and pull system from the Assembly line section toward the Compound/Kitting section. Overflow of incoming material occurs when the pull rate is slower than the push rate. In a reverse condition, shortage of incoming materials happens. That becomes a critical issue to the company.

In producing the Hard Disc Assembly (HDA), all raw materials are assembled in the Assembly section. Each line in the Assembly section consists of 15 workstations which implement one piece flow system. In one piece flow system, one unit is produced at a time, meaning there is no WIP between each step. Once an operation stops, the remaining operators will have to stop working as well, which can create a problem such as production shortage. All materials are assembled in the Assembly section then known as HDA. The HDA are then sent to the Back End section for the next production process. Result of the data analysis determined that the T family product has contributed up to 74% of the total demand, which represents the biggest family product demand. The T family product demand is 6,021,850 pcs in three months and on average 2,000,283 pcs per month or 34,608 pcs per shift. One day consists of two shifts and the production time per shift is 12 hours (720 minutes) and the production runs continuously. The timeline at the bottom of the current state VSM in Figure 3 has two components. The first component is the production lead time (or NVA time). It is obtained by totalling the lead time numbers from the inventory triangle before each process. The time for inventory triangle is calculated by dividing the inventory quantity by the daily customer requirements. The second element of the time line is the processing time (or VA time). It is calculated by summing the processing time for each process in the value stream. In this stage, the cycle time for each process is the average cycle time, which was determined by using actual data, collected from the time study on the company. In this regard, the average cycle time is used to present how well the current operation is doing in relation to the Takt time. Takt time is the unit production rate that is needed to match customer requirements (Abdulmalek and Rajgopal, 2007). It can be determined by dividing the available production time with the total daily quantity required. In this case, the takt time has determined as 1.2 seconds per pcs.

In this case, the current state VSM illustrates the process flow starts thereafter the planner places the materials order to the supplier, the supplier sends the material six times per day (in every four hours). It is recorded that the Non Value Added (NVA) time in the warehouse receiving process is 2.8 hours. The materials are then transferred to the Compound/Kitting section based on the MCS. It is obtained that the cycle time is 30 seconds in Compound and 40 seconds in Kitting. Due to the lack of the proper flow of incoming material, there exists NVA activity between Compound/Kitting section and Assembly line section, which is shown by the high value inventory. It gives impact in longer lead-time that is 0.7 hours. The incoming materials from Compound/Kitting section are then assembled in the Assembly line section. The Assembly section consists of 18 lines, which the cycle time of each line is 12 seconds. After being assembled, the HDA are sent to Back End for the next production process. At this stage, the NVA is obtained as much as 1.1 hours. The ultimate results show that the Value Added (VA) for processing time is 82 seconds, while the NVA is about 4.6 hours. As NVA more than VA, it clearly reveals that the manufacturing process involves lots of NVA activities. The overflow of incoming materials gives impact in the long lead time as a consequence of the big number of NVA. Hence, the NVA activities (i.e. an overflow of incoming materials) should be minimized. The current VSM also indicates high inventory value which is represented by the triangle symbol in between each section. This presented as waste that has prolonged the lead time. In this regards, the high inventory level at Compound/Kitting section happen due to the lack of synchronization of the number of materials delivery from the Warehouse and the rate of material consumption at the Assembly line section. When Compound/Kitting section taking too great number of materials from the Warehouse, it gives effect to the overflow of incoming materials. On the other hand, having too few numbers of materials will greatly diminish the positive effects, making them in the worst case, shortage of materials which leads to the production idle. This makes a redesign of the existing information and material flow system necessary. In eliminating the NVA activities revealed by the current state VSM, a LM technique (i.e Kanban system) is adopted. In this regards, Future state VSM used to visualize how the implementation of Kanban system and show this implementation effect to the current production system. Figure 4 illustrates the result of Future state VSM. From the future state VSM result, the total inventory is estimated can be reduced up to 50% which is only 2.3 hours of inventory. This reduction can be achieved by implementing the pull system toward the entire value stream.

Currently, all materials from the warehouse are sent to the Compound/Kitting section using the push system. The future state VSM recommendation was the current production system should adopt the pull system where the Assembly line produce to a supermarket (corresponding to demand quantity) and move the materials based on the Kanban system. A supermarket is nothing more than a buffer or storage area of materials/products that are ready to be sent to the subsequent process. Whenever the supermarket inventory is below a certain level, this would trigger the preceding workstation to schedule the material/product to replenish the supermarket according to what has been consumed. In this regards, there will be no more excess inventory in each workstation since every workstation will only produce the quantity that is required by its preceding. In conclusion, the current VSM has clearly pointed that the existing materials flow and information flow need to be redesigned. The redesign process shown in the future VSM proposed the Kanban system in order to minimize the overflow of incoming material at Compound/Kitting section. In the meantime, this Kanban system could be able to avoid material shortage as well. In this way, the negative impact of the problem with the performance of the subsequent process can be avoided.

Demand Pattern

Table 1. Demand Classification

Demand Classification	Demand Range			Demand Frequency (2012)		
				February	March	April
Low	10,200	-	24,384	44	3	0
Medium	24,385	-	38,569	12	39	5
High	38,570	-	52,754	0	16	55

For this company, the result of demand pattern analysis shows that planned demand quantity data per shift in every month fluctuates and the changes occur inconsistently. Table 1 presents the demand range and demand frequency as the demand classification result, while Figure 5 shows the planned demand for February 2012 until April 2012. The changes of demand quantity formed a fluctuated demand pattern. In addition, the demand frequency transition between one class demand to the other class demand happened irregularly.

In this study, the pattern of demand changes and demand classification has been used to determine the number of experiments that need to be done in the next phase. From the analysis, it is identified that there are four possibilities of transition between three classes of demand, those are:

- Medium demand to low demand
- Low demand to medium demand
- Medium demand to high demand
- High demand to medium demand

Based on the demand pattern shown in Figure 5, five experiments were designed in order to study the effects of demand class transition to the production performances. Figure 5 also presents the gaps between the planned demand and production output quantity. The gaps are resulted from the fluctuated demand pattern. In this case, the gaps occurred in two different conditions:

Over production

It occurs when the production output quantity exceeds the planned demand quantity. As shown in Figure 5, the gaps denoted by 'a' as the example of over production condition. Further analysis indicates that this gap happened when there is a transition of demand class, specifically transition from medium demand to low demand. When the production output quantity is above the planned demand quantity, Compound/Kitting section must add pulling materials from the warehouse based on the standard lot size. In this case, Compound/Kitting section has to keep this extra material until it is consumed by the assembly line.

Insufficient production

Once the Assembly line section produces output less than the planned demand quantity, it said that insufficiency production happens. As can be seen in Figure 5, 'b' indicates that production output quantity is less than the planned demand. In this case, the shop floor, unable to fulfil the planned demand.

It happened in the condition of demand transition from medium demand to high demand. In this condition, Compound/Kitting section has to keep the unused materials for the next shift production process coupled with the incoming materials which has been scheduled for the next shift. In this regard, the pattern of demand changes and the gaps between planned demand and production output were considered as the factors that contribute to the overflow of incoming materials. Hence, the pattern of demand changes was used as the basis to build FLS. The FLS was proposed to minimize the gaps between planned demand and the production output quantity. In this way, the assembly line section will only produce the exact quantity as is planned demand quantity. As a result, there are minimum excess materials that will be kept in Compound/Kitting section as a buffer.

Proposed Flexible Lot Size for Kanban system

Once the current production simulation model was verified and validated, it is then modified based on the future state VSM. In this regard, the push system at material ordering system is replaced by the pull system. Figure 6 presents the mechanism of Kanban system which is established as the material flow logic in the pull system. Additional locations of Kanban post is introduced in this simulation model. As can be seen in Figure 6, the material flow is started by material and demand arrival at the system. The demand confirms whether HDA is available in HDA buffer. If there is HDA available, the HDA will join the demand and release from the system. Otherwise, the demand is backordered and has to wait for an HDA to arrive in the HDA buffer. At the same time, if the HDA buffer is empty, the demand becomes the signal for the Assembly line section to produce the HDA. To produce the HDA, assembly line section takes the materials from the supermarket that attached with the Kanban. When the materials are consumed, the Kanban is detached and put into the Kitting Kanban post. Then, this detachment Kanban becomes the signal for the Kitting section to pull the material from the Compound section. The same mechanism is also applied in the Compound section and Warehouse. In this study, the FLS was proposed by utilizing the optimization

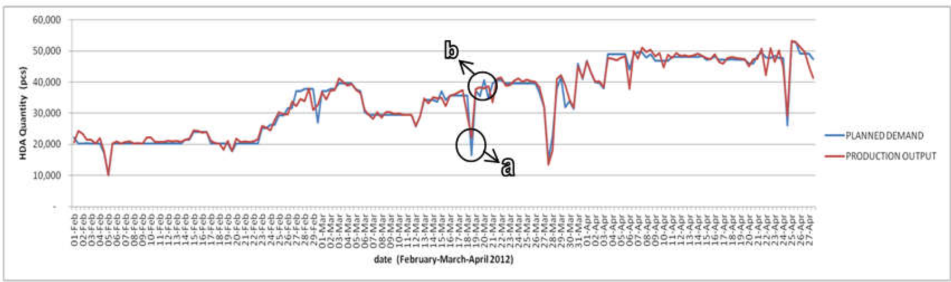

Fig 5. Demand Pattern

Table 2. Optimization Process Result

Experiment Number	Demand Classification	Warehouse Lot size (pcs)			Supermarket Lot size (pcs)			Warehouse Kanban (pcs)		
		MBA	MEDIA	HAS	MBA	MEDIA	HAS	MBA	MEDIA	HAS
1	LOW	361	1600	1536	254	437	256	5	1	1
2	MEDIUM	360	1600	1536	256	402	256	4	1	1
3	MEDIUM	360	1600	1536	256	402	256	4	1	1
4	HIGH	360	1600	1536	260	400	256	5	1	1
5	MEDIUM	362	1600	1536	254	407	320	5	1	1

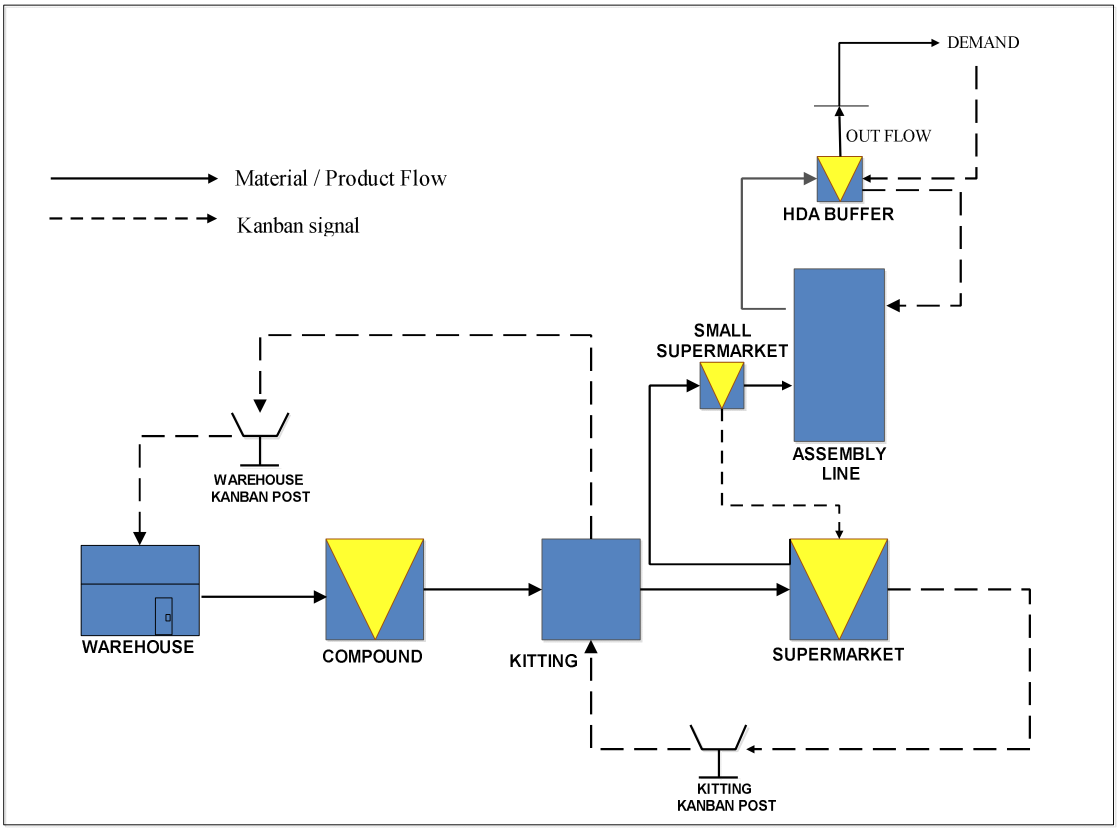

Fig 6. Material/Product flow for Simulation of Kanban System

Table 3. Current Standard Packaging and the Lot size Optimization Result

			Optimization Result of Material Supermarket Lot size for Each Demand Classes		
Components	Current Std Pack	Current Lot size (pcs)	Low Demand (pcs)	Medium Demand (pcs)	High Demand (pcs)
MBA	10 pcs / tray	270	254	254 - 256	260
MEDIA	25 pcs / caddie	600	437	402 - 407	400
HAS	8 pcs / tray	256	256	256 - 320	256

Table 4. Proposed Alternative Standard Packaging of MBA, MEDIA, and HAS using FLS Kanban System

		Optimum Supermarket Lot size Adjustment for Each Demand Classes		
Components	Proposed Std Pack	Low Demand (pcs)	Medium Demand (pcs)	High Demand (pcs)
MBA	5 pcs / tray	255	255	260
MEDIA	10 pcs / caddie	440	410	400
HAS	8 pcs / tray	256	256	256

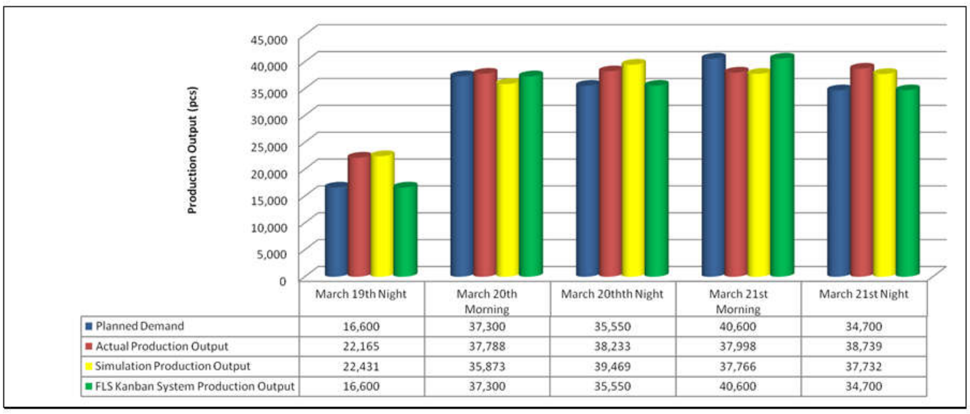

Figure 8. Comparison of Planned Demand and Production Output of Actual System, Simulation Model, and FLS Kanban System

process toward the simulation model of the Kanban system coupled with the analysis of demand pattern. The essence of demand pattern analysis is to study the probability of transition demand class that continually occurred in the production system. From the analysis of demand pattern, there are four transitions of demand classification happened, i.e (i) medium demand to low demand, (ii) low demand to medium demand, (iii) medium demand to high demand, and (iv) high demand to medium demand. In this regard, five experiments were conducted to see all probabilities of the demand changes. Table 2 presents the result of the optimization process. It can be seen that the optimum number of MBA Warehouse lot size between each demand category only has a small difference, which is 2pcs. In this regard, it is suggested to use the current MBA Warehouse lot size, which is 360pcs for all demand classes. Whereas, the optimum number of Warehouse lot size for MEDIA and HAS indicates the similar value with current Warehouse lot size for all demand classes which is 1,600pcs for MEDIA and 1,536pcs for HAS.

for low demand and medium demand, and 260pcs for high demand. In case of MBA Supermarket lot size for low demand and medium demand, if using the current standard packaging 10pcs/tray, there will be five excess MBA. Hence, it is suggested that from the current standard packaging of MBA, 10pcs/tray is split into two which become 5pcs/tray. In this way, the new standard packaging 5pcs/tray can cover the optimum supermarket lot size for low demand and medium demand also high demand without any excess material. As can be seen in Table 4, the proposed practical MEDIA Supermarket lot size is determined as 440pcs for low demand, 410pcs for medium demand, and 400pcs for high demand. While it is suggested to have 10pcs/caddie instead of 25pcs/caddie for the MEDIA standard packaging to put off the excess material for all demand condition. In addition, the proposed supermarket lot size for HAS is 256pcs for all demand classes. This is still following the current standard lot size. Hence, the standard packaging of HAS proposed to follow the initial size which is 8pcs / tray.

Table 5. WIP Inventory in Current System versus FLS Kanban System

				WIP Inventory								
Date	Shift	Demand Classification	Plan Demand (pcs)	Current System MBA	Current System MEDIA	Current System HAS	FLS Kanban System MBA	FLS Kanban System MEDIA	FLS Kanban System HAS	Reduction (%) MBA	Reduction (%) MEDIA	Reduction (%) HAS
March 19th	Night	LOW	16600	1536	2517	1280	312	900	667	76.69	64.24	47.89
March 20th	Morning	MEDIUM	37300	1720	2550	1944	225	1007	544	86.92	60.51	72.02
March 20th	Night	MEDIUM	35550	1268	2848	3672	171	980	545	86.51	65.59	85.16
March 21st	Morning	HIGH	40600	2944	2923	2936	204	953	444	93.07	67.40	84.88
March 21st	Night	MEDIUM	34700	2292	1975	2576	224	903	690	90.23	54.28	73.21
Average			32950	1952	2563	2482	227	949	578	87.3	62.4	72.6

The optimization process result toward Supermarket lot size has shown a slightly different value with the current Supermarket lot size. For MBA the optimum number of Supermarket lot size for low demand and medium demand has significant difference of 14-16pcs with the current MBA supermarket lot size which is 270pcs. Moreover, optimum number of MBA Supermarket lot size for high demand has 10pcs difference with the current lot size. In the meantime, the optimum number of MEDIA Supermarket lot size has a significant difference compare to the current MEDIA Supermarket lot size. The difference is reaching 163pcs for low demand, 193-198pcs for medium demand, and 200pcs for high demand. Meanwhile, the optimum number of HAS Supermarket lot size has the same value with current lot size for low demand and high demand, which is 256pcs. In addition, the optimum HAS Supermarket lot size for medium demand is chosen to be 256pcs; even though it can reach value 320pcs in fifth experiment.

In Compound/Kitting section, Kanban system is new to the production system. In this study, the proposed Kanban number follows the optimization result. The optimization result shows that the optimum number of Kanban is the same for all demand classes, which is five Kanban for MBA, one Kanban for MEDIA, and one Kanban for HAS. Based on the optimization result shown in Table 2, the small different of Supermarket lot size number can be adjusted for the entire demand classes by proposing a new standard packaging of each material so that practical lot size can be suggested. Table 3 shows the current and optimization result of Supermarket lot size, while Table 4 presents the proposed Supermarket Lot size for each material in each demand classes. The proposed supermarket lot size for MBA has been determined as 255pcs

Figures 8 shows the differences between actual, current production system simulation, and FLS production output toward the planned demand. In March 19th night shift, the production output quantity of actual and current production system simulation model was above the planned demand. It shows the lack of current production system, where the production output quantity different with the planned demand. Whereas, by using FLS, the results show that the production output quantity has met the planned demand. In this way, the proposed FLS enable to minimize the overflow of incoming materials proved by the reduction of the average number of WIP inventory at Compound/Kitting Section. Table 5 presents the WIP inventory status of the current condition compared to proposed FLS. This table shows that the WIP inventory in Compound/Kitting section has drastically reduced as many as 87.3% reduction for MBA, 62.4% reduction for MEDIA, and 72.6% reduction for HAS.

Concluding Remarks

This paper presents a case study on the hard disc assembly process that facing an overflow of incoming materials in Compound/Kitting section. The causes of this problem have been well identified using VSM. The first objective is achieved as the current VSM and future VSM successfully constructed. The current VSM is used to understand the current Compound/Kitting production flow in terms of the system layout, demand quantity, production wastes, also a visual flow of material, and information flow. Through the VSM, root-cause of the incoming materials overflow has been identified, as lack in ordering system that causes the high inventory in Compound/Kitting section. The second objective is achieved as the demand pattern successfully determined. It shows that the current system has a fluctuated demand that forms gaps. The fluctuated demand and the gaps between planned demand and production output have contributed to the overflow of incoming materials in Compound/Kitting section. This paper proves that the overflow of incoming materials in Compound/Kitting section can be minimized through implementation Kanban system with FLS.

The proposed FLS able to distribute the right materials in the right quantity in the right place and at the right time as the planned demand. In addition, up to 87% of the average of WIP inventory value in Compound/Kitting section has been decreased. Although the result shows a significant reduction of WIP inventory value, the adopted Kanban System uses manual Kanban card as the information signal. Essentially, FLS Kanban System is developed in satisfying the quickly changing environment. Hence, instead of using card, the information of pulling material will be delivered through electronic media such barcode or electronic messages. In this case, it is necessary to study the establishment of the electronic Flexible Lot Size Kanban System (e-FLS) in order to enhance the efficiency of hard disc assembly process.

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