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Design framework of a smart Kanban system for Malaysian automotive mixed model assembly line

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Abstract: This paper describes the design development framework of a smart kanban system for Malaysian automotive mixed model production line using NetBeans platform to build a desktop java application and construct a graphical user interface. The complexity of manual kanban system has increased with the increase of product variety in mixed model production area and thus caused the kanban system to be inefficient due to problems such as wrong application of kanban type, production delay and wrong order due to incorrect number of kanban card in the system, insufficient inventory and late information to production area. Moreover, ability to transfer production orders information from downstream to upstream by the material handler on time is always disputed. The system development objective was to solve the dynamic and complex problem of production planning and improve and strengthen the subject company. Therefore, by this research a smart kanban system developed and reorganized. The information flow within the production area will be reorganized and the system is designed to exhibit misconduct and self-correct the information. The presented framework should improvise the material and information flow within the production line while the user can view data and gain real-time visibility into the mixed model production line.

Key words: Kanban system; Mixed model production; Electronic kanban system; Automotive; TPS

1. Introduction

The complexity of manual kanban system has increased with the increases of products variety in any mixed model production area. The complexity can be seen when the number of model produced increased within one production line. This situation frequently end-up with manufacturing problems such as production delay due to wrong order and incorrect number of kanban cards in the system, insufficient inventory and late information to production area. Furthermore, in reality the situation is always not perfect; there are surging orders, machine breakdown, high fluctuation of demand and operation failure. Shortage of the delivery will then occur and the only solution is to have a huge amount of safety stock which contributes to an increase in inventory cost.

The limitations of conventional kanban are information storage, transferring and effective production line balancing and the development of information technology that contributes to a new kind of kanban known as the electronic kanban which is important in mixed model production system (Haiyan, 2012). Paper kanban card and its data are complicated to transmit directly to computer information system. Additional worker is necessary to computerize all the information and increases the error during data manual entry (Qing et al., 2011). The loss of kanban card often occurs and causes the plan and the forecast prediction ability insufficient. Other than that, for high fluctuation mixed model product, the frequent changes of the manual kanban is easy to make mistakes and the kanban storage is also a problem.

An electronic kanban system has been introduced and applied by many manufacturers around the world in order to solve these problems. The electronic kanban has not changed the method of original kanban invented by Japanese companies; however, it boosted and improved the application of kanban in production line in terms of accuracy and rapidity (Jun, 2007). Besides, electronic kanban can be the alternative to material flow control in high fluctuation demand situation (Tardif and Maaseidvaag, 2001).

The advantage of electronic kanban is the alertness of the real kanban procedure and situation. The visualization of kanban system can display overall and real-time of various working procedures and actual situations on the computer screen (Qing et al., 2011). For example, when abnormal situation occur, the electronic kanban system can adjust production scheduling by using good man-machine interaction and promote validity for all kinds of situation.

Nevertheless, the manual kanban system in plant manufacturing areas is still the main option of practice because it produces exact number of products to be delivered and contributes to low implementation cost. Therefore, in this research, the limitations of the manual kanban system will be

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identified and rectified by offering a new framework called the Smart Kanban System (SKS). Attention will be given on the reliability of the framework as a practical tool to be used by manufacturers to choose the right type of kanban and to calculate the right number of cards based on customers' real demand. The framework developed is standalone without internet connections thus ease information access anytime or anywhere. Provided with a friendly-user interface, the shop floor worker may also generate data and solution from the framework.

2. Literature review

2.1. Mixed model production

In mixed model production line, different products are produced in the same production line according to production schedule and order quantity (Zemczak, 2014). Correct balancing of production sequence in mixed model production will result in remarkable impact on efficiency. The more variety of product types leads to increase complexity in line balancing (Jun- Xia et al., 2010). Usually, the order quantity is in a small lot and the products are grouped based on their similarity in terms of process steps, machine and materials (Chan, 2001). This is to reduce inventory, eliminate difficult production line changeovers and improve manual kanban operation. However, when dealing with Just in time (JIT) through kanban which emphasizes on actual market needs, the adoption of conventional kanban has created a lot of problems such as kanban information errors, limited tracking capability and misplaced of kanban card (Wan and Chen, 2008).

By implementing a proper sequence will result the operator to have sufficient time to complete all assembly operations (Marcin and Damian, 2014; Solnon et al., 2008). Previous studies showed that implementing mixed model production system can also improve the output in terms of profitability, reduce production waste and increase efficiency. For example, if proper procedure for mixed model production is adopted such as proper scheduling of workers' utility, there is a potential of cutting labor costs (Gujjula and Gunther, 2009).

2.2. Electronic Kanban system (E-Kanban)

Many manufacturers nowadays switched to electronic kanban system which is computerized with web-based technologies (Jarupathirun et al., 2009; Jun-li et al., 2013). Electronic kanban is generally a kanban that stores the information in database, while user interface is used to display the information (Jun, 2007). Electronic or e-kanban system is described as a variation to kanban with only one modification, namely the substitution of physical signal to electronic signals (Hu et al., 2012). E-kanban helps to remove problem of lost cards, minimizes material shortage, improves the supply chain transparency and helps to analyse supplier efficiency (Wan and Chen, 2008; Jarupathirun et al., 2009).

In-plant manufacturing area, manual kanban card is still the main option because it presents actual product at the storage or on the manufacturing floor. Moreover, e-kanban can reduce all the conventional technique that produces many wastes such as wasting paper and adding cost to create kanban card, non-flexible management and low efficiency (Naik et al., 2013). Another existing study claimed that electronic kanban may help especially in mixed model production to visualize the information of process, production schedule and resource working hour on the computer screen (Haiyan, 2012). In addition, it can make interaction between manager and whole production process and information dynamically while monitoring and controlling the production.

Furthermore, the implementation of the e-kanban system can more or less increase the translucency of supply chain between the supplier and the production area (Naik et al., 2013). In addition, real time various working procedure and actual condition can clearly be observed and displayed by the e-kanban system (Wang, 2012). Moreover, the e-kanban can auto-update the kanban information which can ease the workers' tasks (Hu et al., 2012) as a product transferred follow the sequence the accuracy and speed of information flow and material flow increases (Jun-li et al., 2013). Therefore, many more potential quality problems can be avoided (Hu et al., 2012). Furthermore, it helps to enhance the pull system in terms of production efficiency, reduce waste, and shorten planning schedule (Shingo, 1998).

Many studies have shown that the e-kanban is economical (Hu et al., 2012). Nevertheless to implement this e-kanban system, it is very important to an organization to consider the financial aspects. The electronic kanban involves high investment at the beginning stage (Naik et al., 2013). Eventually, the electronic kanban is invented to substitute the manual kanban which aims at being more responsive and with lower inventory cost, and the main varianceò about the electronic kanban is being reconfigurable in terms of the total number of kanban (Mohanty et al., 2003). Based on electronic kanban developer, an electronic kanban features can automatically correct the size of inventory based on demand change (Electronic Kanban, 2014). Likewise, it may optimize production sequencing based on information from downstream.

3. Smart kanban system design approach

3.1. Current situation in subject company and research area

UMW ADVANTECH SENDIRIAN BERHAD (UASB) is a local automotive component manufacturer which is located in Shah Alam Selangor. This company is a leading manufacturing company with 30 years' of experience in auto component business and plays an important role as a main automotive component supplier for local and foreign car makers in Malaysia. Currently, UASB produces a variety of filtration products such as air cleaner module, cylinder head cover, charcoal canister, fuel filter, oil filter and hydraulic filter.

Air cleaner BLM line has been identified as the most appropriate line to adopt the smart kanban system. This line produces four different air cleaner models within one day which includes injection molded sub and child parts. The kanban system practiced at the line is the conventional system using kanban card and kanban post. The additional tools such as work order is still being practiced as an instruction document and it is an important requirement to store the production information. Fig. 1 shows the material and information movement for the air cleaner BLM line and the movement can be two-way.

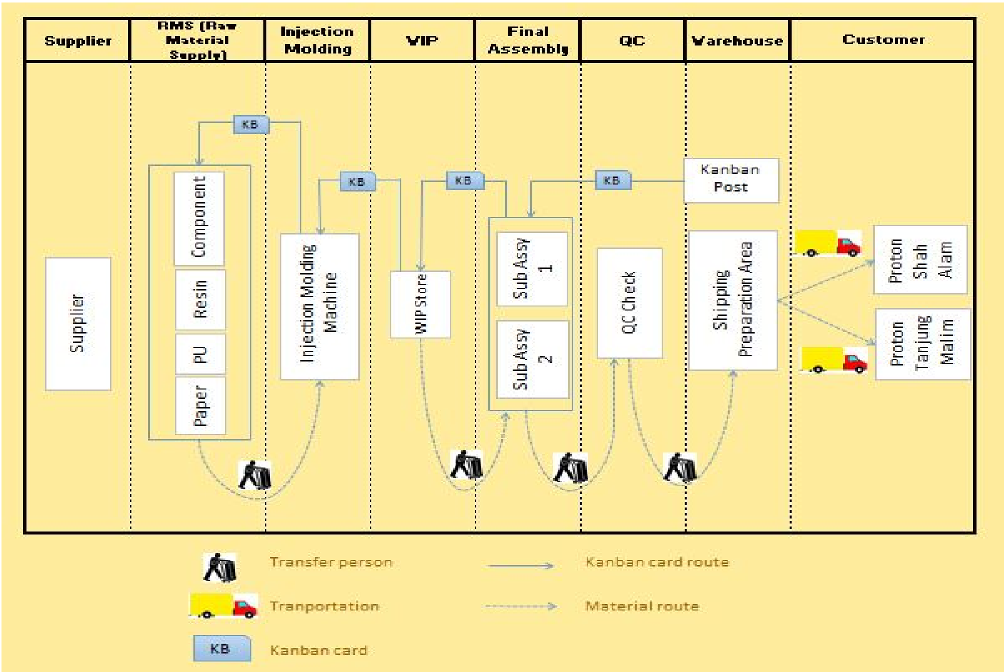

Fig. 1: Material and Information Flow Chart (MIFC) of the research area

The material handler moves around the production area according to schedule. However the material flows are based on visualization of the material handler. There is no instruction or signal given to the material handler to delivery material, whereas the empty stock will be filled up when the operator enquires for the parts. Thus, there is no proper schedule for the material handler to deliver the materials.

Besides, the kanban card is often lost within the production area. This is due to negligence while putting kanban cards into the empty polyboxes. Consequently, the production instruction becomes incorrect. Hence, the daily demand is not achieved and thus disturbed the delivery status. Whereas, to ensure that the daily delivery status meet the 100% as per customer requirement, there will be large inventory stocked up and leads to high cost for warehouse and storage.

3.2. Design of smart Kanban system framework

The framework developed integrates two work stations which are assembly line and store (WIP and shopping area). The system involves final assembly area, WIP, injection molding area, RMS and shopping areas. The information flows from upstream to downstream which is from final assembly to shopping area.

The framework is to ensure the correct movement of information and goods within the production line. The good/material is to be replenished and transferred to the preceding process where it is then produced and delivered. The framework developed with a friendly graphical user interface (GUI) enables all level of workers to use. Therefore, human error can be avoided. There are several features of the proposed system which are based on existing electronic kanban systems that are commercially available but have been designed specially tailored to the production needs of the subject company. The features are as follows:

3.2.1. Simple and easy for workers to use

The framework's interface was designed to be smart and practical that can be used by all level of workers from management to shop floor workers. With minimal monitoring, the shop floor workers can handle the framework by themselves. The purpose is to minimize the training session conducted for them. Thus, it can reduce time, paper work and handling. The framework developed is a user-friendly interface. The graphical interface is easy to understand and can be directly use. As shown in Fig. 2, the home page lists all the menus or options for the worker to select and key-in the input.

Fig. 2: Smart Kanban system home page

3.2.2. High visibility

If any regular and common problems occur such as product shortage, information movement disputed and supply chain problem, these can be catered immediately and eliminated. This is due to the movement and stock of RMS, part inventory and WIP are able to controlled and monitored by the computer screen. Thus, it leads to performance and accuracy improved.

3.2.3. High workstation operation integration

This framework integrates the two stations which are assembly line and store using internet network. However, the framework is built on localhost which means it can be used without any internet network and it can be stand-alone. Thus, this may assist to improve the speed and quality of operations management.

3.2.4. Low cost implementation setup

The full set up cost is extremely low. There are no additional tools needed except for a notebook. Comparing to the established electronic kanban system in the market, most systems use barcode and require a receiver and transmitter tools which may be costly. Moreover, the low cost system may lead to reduce cost while the kanban card and kanban box cost can be eliminated. Besides, the software used is free for users.

3.2.5. Inventory alert

Inventory level will always be monitored and controlled efficiently. The inventory will be updated constantly and according to schedule using this framework. It can be visualized through the computer screen. Therefore, if abnormal condition occurs it can be corrected immediately.

3.2.6. Dynamic scheduling

The scheduling for withdrawal part will be more exact and will not pass over. Compare to existing situation, the part produced is not well organized even the production instruction (PI) are given because of PI late arrival. The reorder point can also be schedule follow the appropriate procedure. Thus, the efficiency of the material handler will be improved generally.

4. Result

4.1. Factors limiting the conventional kanban system

4.1.1. Operator's skill and knowledge

Most of the shop floor worker has low education background and frequently change. Therefore, the objective of training workers to enhance their working skills is not easily achievable due to the frequent change at the workplace. Besides, creativity of worker in terms of problem solving is low. As a conclusion, the existing kanban systems in the production area are improper and do not follow the standard procedure.

4.1.2. Late information to production area

The information flow is always distracted caused by loss of kanban card or card being misplaced and thus causes delay in arrival of information. Fig. 3 shows the kanban cards were inserted to the polyboxes that cause losses of kanban card. The kanban card can be simply misplaced at the polyboxes without any proper attachment. Therefore the probability of kanban card loss is high.

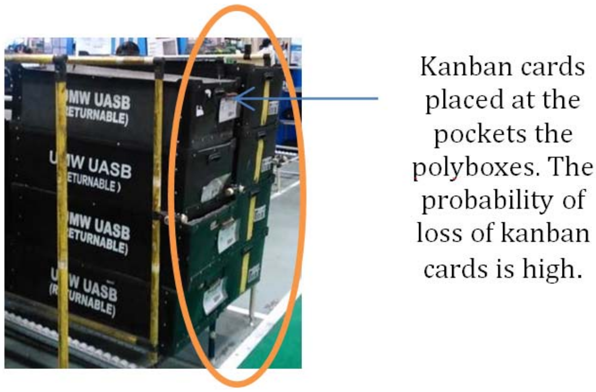

Fig. 3: Kanban card inserted at polyboxes

4.1.3. Kanban tools

The existing kanban tools are not efficiently applied. The practices of using these tools should be standardized throughout the shop floor and clearly made aware to all workers. In order to realize the mixed model production on floor, it was necessary to establish the appropriate kanban tool. This is to ensure that the kanban information would be delivered to the right place at the time following the schedule arranged.

4.1.4. Material handling system

In the production area, the material handling system used an improper approach in terms of scheduling and travelling route. There is no proper schedule for material handlers to travel around production area. There is no appropriate indicator to the material handler as signal to deliver parts. Therefore, movement is based on their visualization at the production area. Consequently, the shortage of part at work station occurs often. Thus, the framework proposed can provide efficient and smooth movement of material and information flow in the production area.

5. Framework development

Through adopting the NetBeans platform and localhost technology, the real time status information of production area could be collected, which provides a basis for the comprehensive monitoring management. This smart kanban system consists of three layers, namely are the hardware supporting layer, information layer and user application layer. The details of each of these layers are described as follows:

5.1. Hardware supporting layer

This layer includes the hardware and software component. For this framework, the notebook is the hardware used to ensure that communication and monitoring works well. The notebook is chosen due to its light weight and mobility. Thus, it is easy to carry around in the production floor.

5.2. Information layer

In this layer, the production management captures and manages the information as shown in Fig. 4. This layer includes the static and dynamic information. All the data are illustrated using Java language. Static information consists of information that does not require any change once created. It will only be changed or updated if any modification or enhancement is necessary. However, the dynamic information changes frequently within the week or month.

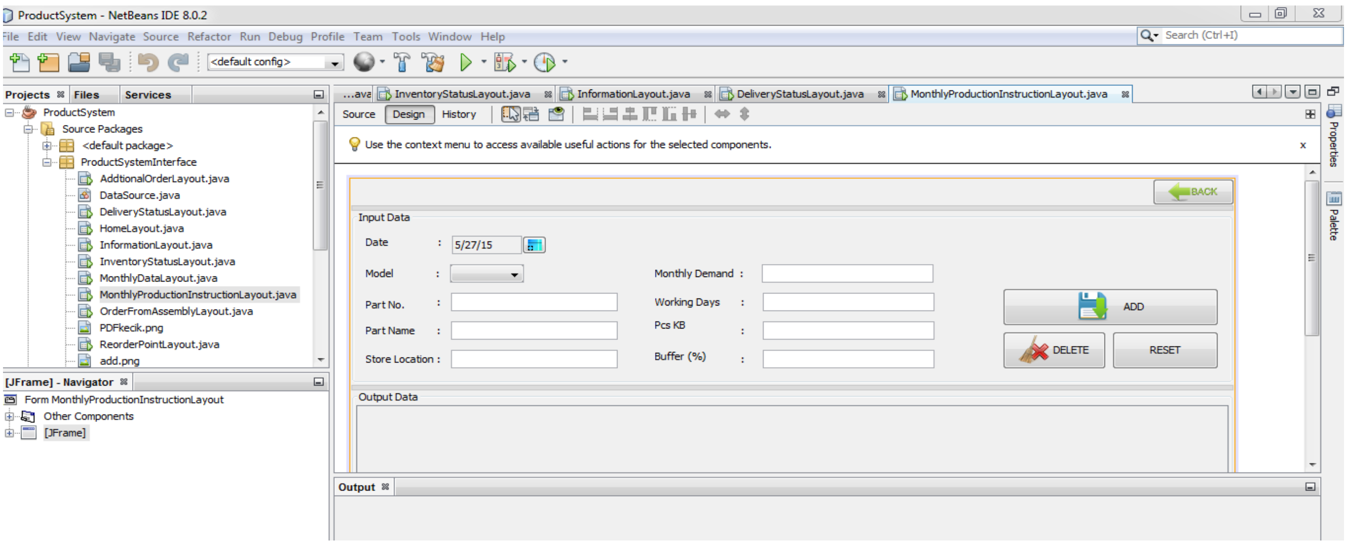

Fig. 4: Layer of Information and data integrate; User Application Layer

This layer is the interactive interface between the user and data. Graphical view is used to allow the user to view and analyze data regarding the information and goods flow. As shown in Fig. 5, the user manually key-in data input, to vary input cell which is their calculation fixed in the framework. Then, the output will display all the information necessary to run the production activities which should synchronize with the inventory status, safety stock and buffer stock which is not only dependent on the forecast given by customers.

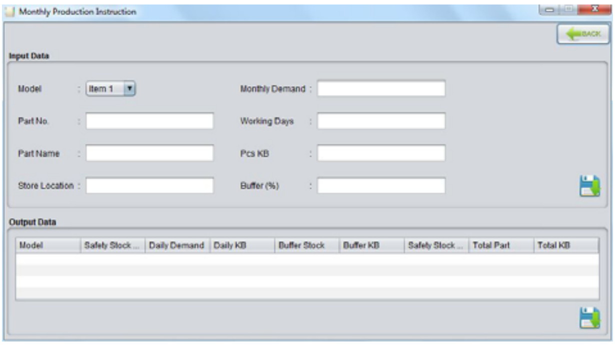

Fig. 5: Graphical user interface of the system

6. Conclusion and further work

In this paper, the factors limiting the conventional kanban system were identified. The factors are low operators' skills and knowledge background, late information arrival from upstream to downstream, improper kanban tools used and unorganized material handling system. The system was established to solve the existing problems at the subject company. By using the system, even operators with low skills are able to carry out the tasks. Besides, the use of kanban tools such as kanban card and kanban post can be reduced thus cutting down the implementation cost. Furthermore, by comparing to existing electronic kanban systems, utilizing a friendly software and java language, makes the document management system easier, user-friendly, and also bears low maintenance cost. Next, the production information flow will not dispute and the material handling system efficiency will improve.

The future works will focus on the following direction:

Firstly, the framework will undergo a reliability test. In order to enhance the reliability of the framework, after completing every steps of development, the system will be checked. Should error exists, the source of error is identified and corrective action is made accordingly. Next stage, once the system has proven to be fully reliable, it will then undergo on-site integration and testing using historical production performances data to ensure accuracy. Lastly, the system validation process will establish documented evidence that the computerized system will constantly perform as intended in its operational environment. This is verified by comparing the data separated with the system against the existing kanban system of the company.

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