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Integrating Big Island Layout with Pull System for Production Optimization

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***Abstract*—**Lean manufacturing is a production philosophy made popular by Toyota Motor Corporation (TMC). It is globally known as the Toyota Production System (TPS) and has the ultimate aim of reducing cost by thoroughly eliminating wastes or muda. TPS embraces the Just-in-time (JIT) manufacturing; achieving cost reduction through lead time reduction. JIT manufacturing can be achieved by implementing Pull system in the production. Furthermore, TPS aims to improve productivity and creating continuous flow in the production by arranging the machines and processes in cellular configurations. This is called as Cellular Manufacturing Systems (CMS). This paper studies on integrating the CMS with the Pull system to establish a Big Island-Pull system production for High Mix Low Volume (HMLV) products in an automotive component industry. The paper will use the build-in JIT system steps adapted from TMC to create the Pull system production and also create a shojinka line which, according to takt time, has the flexibility to adapt to demand changes simply by adding and taking out manpower. This will lead to optimization in production.

***Keywords*—**Big Island layout, Lean manufacturing, Material and Information Flow Chart, Pull system production, TPS.

I. Introduction

LEAN manufacturing is not just a cost reduction program or a problem solving approach. It is a manufacturing concept in which its main idea is that an efficient production can be achieved by a comprehensive approach to minimize wastes or muda [4]. This means eliminating excess production and inventory, over processing, redundant movement of material, waiting and delays, excess worker motion, and the need for rework and corrections. Part of lean manufacturing is reviewing operations for those components, processes or products that add cost rather than value [6].

Each step of the manufacturing process is monitored to determine if it adds value to the product. If it does not add value, continuous improvements or kaizen must be made. Lean manufacturing has been developed, practiced and made popular by Toyota. It is known as the Toyota Production System (TPS), developed by Toyota Motor Corporation (TMC), has the aims of reducing costs by thoroughly eliminating muda [4]. There are 7 types of muda that can be categorized which are muda in over production, repair, inventory, waiting, transportation, process and motion. Among all the muda stated, the muda in over production is the most dreadful muda [2]. A company that over produces its product will face these problems in their operations:

1) Usage of materials ahead of the needed consume time
2) Over usage of resources such as manpower, energy, equipments.
3) Over produce creates extra stocks
4) Need to have more warehouses to keep the stocks
5) Need to have more resources to handle the stocks and control them
6) Capital tied up in the stocks leads to loss in bank interest rates
7) Stocks eliminate the needs for kaizen

According to TPS, the ultimate way to avoid over producing and eliminate muda in over production is to implement the Just-in-time (JIT) production. JIT production is a production system that enables the concept of producing what is needed, when it is needed and in the quantity needed according to customer demand.

A. JIT Production

The backbone principle in shortening the lead time of manufacturing is the Just-in-time principle. The aim is to achieve cost reduction by lead time reduction. In 1938, on the completion of the Toyota Koromo Plant, Kiichiro Toyoda stated that he plans to cut down on the slack time within the work processes and in the shipping of parts and materials as much as possible by adopting the Just-in-time approach. In this principle, the next process is regarded as the customer and they are provided with the required amount and quality of goods and services on a timely basis [5].

There are 3 basic principles behind the Just-in-time concept which are:-

1) Pull system; the upstream process pulls what is needed, when it is needed and in the amount needed from the preceding process.
2) Continuous flow of process; the arrangement of the process layout complements the process flow.
3) Takt time; produce according to the customer demand rate. The formula for takt time is as follows [1]:

$$\text{Takt time} = \frac{\text{Time available during the period}}{\text{Customer demand in the period}} \quad (1)$$

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B. Cellular Manufacturing System (CMS) and Big Island Layout

Cellular manufacturing is the grouping of similar products for manufacture in discrete multi-machine cells. [3]. It is based on the principle of Group Technology where machines are arranged together in “cell” orientation according to the product family. The objective of this kind of layout arrangement is to improve material flow, reduce stagnation of WIP stocks, reducing production lead time as well as having flexibility to the production line to cope with volume fluctuation. Big Island layout is a layout concept of connecting two or more isolated cells to become one merged cell. There are 3 types of Big Island connection methods:-

1) Same takt time connection method
2) Various parts mixing connection method
3) Different takt time connection method

By connecting the isolated cells to become Big Island, continuous flow in production can be promoted as well as full work load can be given to the operator that is assigned to the cells. Most importantly, abnormality can be grasped at a glance.

C. Material and Information Flow Chart (MIFC)

As its name implies, MIFC is a tool which uses a set of symbols to chart the production in terms of the flow of information and material. Applying of MIFC is in a form of process flowcharting, with a set of standardized icons and diagramming principles which through that all the material and information in the flow will be clearly shown [7]. This study utilizes the MIFC to understand the current production system as well as to design the Pull system. The list of symbols used in this study is shown in Fig. 1.

Term	Symbol	Term	Symbol
1) Material Flow	→	5) Heijunka Post	
2) InformationFlow	- - - →	6) Kanban Chute	
3) Part Withdrawal Kanban		7) Production Line	
4) Prod Instruction Kanban		8) Line store	

Fig. 1 MIFC Terms and Symbols

II. PROBLEMS AT AN AUTOMOTIVE COMPONENT INDUSTRY

This study was done at an automotive component manufacturer production line. The manufacturer produces air cleaner module as one of their product to be supplied to various auto maker in Malaysia. The models produce here are of HMLV, where there are a series of models to be produce but the order quantity of each model is small. The air cleaner product has 11 models which from the 11 models, 8 of them are considered as low volume models. For this study, focus is given to 4 low volume models which are MPV, D35N, HON and WRM. The part numbers are produce in isolated manufacturing cells according to the models. The current cell layout is shown in Fig. 2.

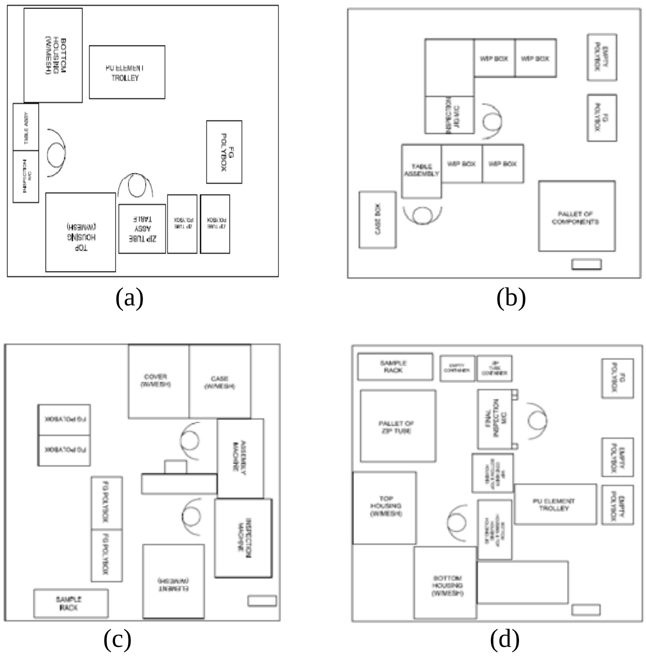

Fig. 2 (a) WRM (b) HON (c) D73A (d) MPV production cells

The following are the list of problems the study highlights regarding the current production method:

1) Production are run and scheduled according to monthly forecast and scheduled planning. The production is not tied up with sales and customer requirement thus over production of some models and parts shortage of some models frequently happen. Moreover, by planning, it leads to high raw material and finish goods, high work-in-process (WIP) stock resulting in stagnation of parts flow. The production lead time becomes long and creates a lot of non-value added activities.

2) The cells are arranged in isolated islands; far away from each other thus limit the sharing of workload between the operators. In TPS terms, this is called Fixed Manpower Configuration cell and it has no flexibility to adapt to demand changes. For instance, if the cell only needs 1.3 workload of manpower to run the cell, 2 operators are needed to be assign to the line for production. This will lead to either muda in over production or muda in waiting to happen.

3) The cells use wire mesh (Fig. 3) as component supply. This leads to big production lot size of the models and creates too many WIP stocks (Fig. 4). It also utilizes more space.

Fig. 3 Wire mesh

Fig. 4 WIP Stocks

4) Operators workload and cell utilization rate is unclear. There is a poor visualization on the production cells.

III. Recommendations

To address to the problems stated, the study propose on implementing a Big Island-Pull system production for the production of the 4 models. The steps to realize the system are as follows:

1) Do production according to takt time to allocate number of operators to the Big Island with respect to the work load based on takt time. Takt time analysis is done.
2) Improve the CMS layout by forming a Big Island Production Cell.
3) Improve the cell parts supply by using flow racks to substitute the usage of wire mesh pallets.
4) Tie the production speed with sales speed by implementing Pull system production using internal kanban. The Pull system is designed using the MIFC.
5) Integrate the Big Island production cell with the Pull system

A. Production According to Takt Time

Table I is the takt time analysis done on the 4 models. According to the customer demand, the total monthly production requirement is 10920 pieces.

TABLE I
Takt Time Analysis

Model	Monthly prod. requirement	Working days	C. T	Weighted average (WA)	W.A.C.T
MPV	3320	20 (b)	114	0.30	34.20
D35N	6280		52	0.58	30.16
WRM	600		124	0.05	6.20
HON	720		155	0.07	10.85
Total	10920 (a)				81.41

The daily production requirement can be calculated by dividing (a) and (b). The daily requirement is 546 pieces for all the models. Daily working time available is 475 minutes or 28500 seconds. The takt time can be calculated by using equation 1.1.The takt time is 52.2 seconds. The number of operator needed to run the production can be decided by dividing the W.A.C.T with the takt time.

$$\text{Needed Operator} = \frac{\text{W.A.C.T}}{\text{TT}} = \frac{81.41}{52.2} = 1.55 \text{ manpower}$$

B. Big Island Layout Formation

In order to address the problems stated, the study suggest on doing improvement on the cell layout. The 4 isolated cells are merged together to form a big island using the different takt time connection method. The big island formation is shown in Fig. 5.

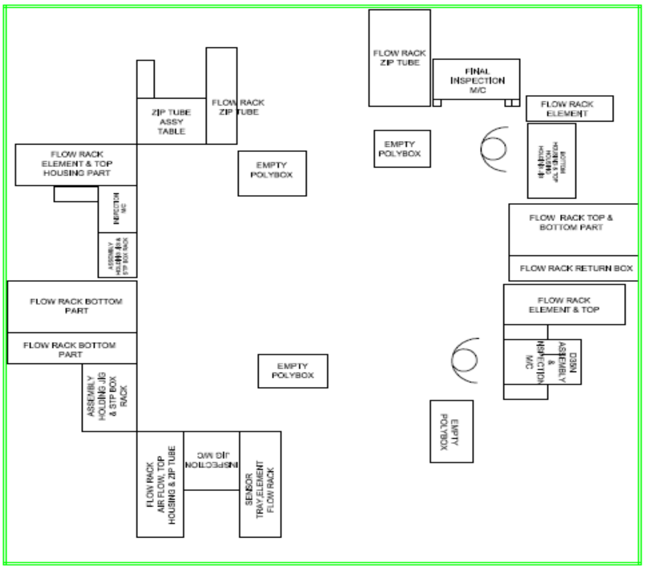

Fig. 5 Big Island Cell

C. Flow Rack Supply System

Furthermore, in the big island cell, flow racks are used to replace the wire mesh pallets. The components parts are supplied to the cells in boxes designed according to the lot size. The pictures of flow racks and boxes are shown in Fig. 6.

Fig. 6 Flow Racks and Boxes

The usage of flow racks reduces the space utilization of the cells and also reduces stock in the production line.

D. Creating the Pull System Production

The study designed the system using MIFC. Appropriate system tools are used in the MIFC to design the most suitable Pull system for the production line. In order to have a levelled pulling effect, Heijunka post is used. Line Store is designed into the system to place the FG and the kanban chute is used to place the kanban sequence. As for the internal kanban, dual kanban system is adopted, usage of PW (Parts withdrawal) and PI (Production Instruction) kanban. The system diagram is shown in Fig. 7.

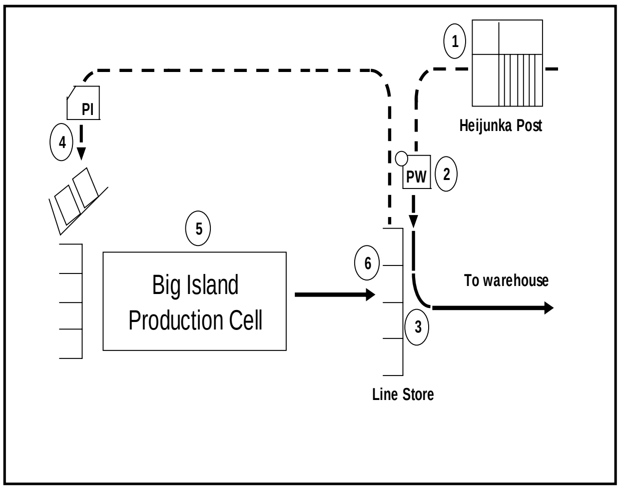

Fig. 7 Pull System Diagram

To create the system, the study uses the following step which is adapted from TPS.

Step 1.0 Place the store where it is produce
Step 1.1 Transfer the sales speed to the production lines
Step 1.2 Produce according to kanban pull sequence
Step 1.3 Increase line reliability

In step 1.0, a line store is placed at the big island cell. The line store is used to keep a calculated amount of FG stock to realize the supermarket pull to the warehouse according to the customer demand. Fig. 8 shows a picture of the line store.

Fig. 8 Line Store

In step 1.1, the sales speed is transferred to the production lines by using the PW kanban. The PW kanban represents the order of production to the lines according to what that has been sold to the customer. In this study, a heijunka post (Fig. 9) is used to level the production so that the big island cell produces the 4 models alternately with respect to customer demand.

Fig. 9 Heijunka Post

Once the parts at the line store are pulled, the PI kanban which is attached to the parts in the line store is taken out and placed in sequence on the kanban chute. The parts taken from the line store are sent to the warehouse. The next step is step 1.2, where the parts are produce according to the PI kanban by sequence. The PI kanban is the tool to instruct the line on what part to produce. Once the production is completed, the parts will be placed on the line store. Note that the production line produces and replenishes what has been pulled from the line store from the previous cycle only. This cycle will continue each time there is a customer demand pull. Finally, in order to ensure the parts are produce by JIT and at a short lead time, step 1.3, increase the line reliability is taken.

The Pull system mechanism can be summarized as follows:

1) The PW kanban of the parts that the customer has pulled is arranged in leveled arrangement in the heijunka post. The heijunka post has a time scale of 15 minutes, meaning every 15 minutes order is sent to the production line.
2) Once the time for pull arrives, the PW kanban is taken from the heijunka post and the kanban is used as a signal to pull the parts needed from the line store.
3) At the line store, the parts are attached with PI kanban and are ready to be pull accordingly. The parts are pulled from the line store using the PW kanban and brought to the warehouse for delivery.
4) The PI kanban attached on the parts are taken out and put on the kanban chute. This act as the ordering signal for the production line to produce what the customer has pulled from the previous cycle.
5) The production line will produce parts according to the PI kanban sequence which is leveled between the 4 models.
6) Once produced, the parts are stored at the line store, replenished and ready to be pulled by the next kanban cycle, according to customer demand.

IV. Results

The results from this study are summarized in Table II. The results show big improvements in terms of lead time, WIP stocks, production floor space utilization and usage of operators. Moreover, the productivity after implementing the Big Island cell is higher compared to the previous one. This is mainly because of usage of less manpower and full utilization of the operator's workload. Integrating Big Island layout concept with Pull system production yields production optimization.

V. Conclusion

The automotive component industry in Malaysia could not help but to supply to various carmakers of different companies. This is to achieve enough production quantity for making ends meet. By producing many products for several carmakers, the industry will have to cope with producing HMLV products. Producing HMLV products without carefully planning will lead to problems such as over production, production instability and inefficient use of manpower.

TABLE II
Summary of Results

	Lean Metric	Unit	Before	After	Improvement
1	Assembly Lead time	Days	3.22	2.14	Reduce 34%
2	WIP stock				
	a) WRM		499	24	Reduce 95%
	b) HON	Pieces	640	18	Reduce 91%
	c) D35N		408	40	Reduce 90%
	d) MPV		499	36	Reduce 93%
3	Space	Sq. ft.	1350	939	Reduce 30%
4	Operators	Man	6	2	Reduce 67%
5	Productivity				
	a) WRM		27.3	29.0	Increase 6%
	b) HON	Pieces / ManHr	7.2	23.0	Increase 219%
	c) D35N		60.0	69.2	Increase 15%
	d) MPV		13.2	31.6	Increase 139%

Big island-Pull system is a concept that can be adapted by the industry to handle this matter. The system can be designed into any production and it can benefit the company by managing the production better in terms of stock, lead time and manpower usage, thus optimizes the production. The Big-Island Pull system concept is also able to instill flexibility to demand changes in the production line thus making the production line nimble to any fluctuation in production. Furthermore, cost reduction can be achieved by shortening the lead time, in the sense of producing just-in-time.

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