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The effect of the supply chain in the quick response manufacturing (QRM) environment in the automotive industry

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Abstract

The manufacturing industry is having an issue regarding the quality of the company's planning to produce efficient performance throughout the year. The improvement needs to be carried out to give customers considerable satisfaction regarding the quality of the products and the delivery time. As the manufacturing industry evolves throughout the decades, the demands are becoming more challenging: faster delivery and better quality of products. The markets will interrupt a good supply chain of a company. The Quick Response Manufacturing (QRM) approach significantly benefits companies whose focus is on lead time reduction. This study aims to reduce the lead time and to improve the supply chain of a selected automotive production line by using Witness software simulation. The improvement also sought to implement the Just-In-Time (JIT) inventory management method. The data collected from company X is simulated to get the percentage of idle, blocked, and overall process time. By using the data from the selected line, the improvement of the overall process time is 27.5%, meaning that the company is ready to implement the JIT inventory management method.

Keywords: "Quick response manufacturing, Automotive Industry, Supply chain ;"

1. Introduction

Recently, the manufacturing industries are having a hard time adjusting to the current economic globalization issue. The focus is now on the customers' demand for faster delivery of their products [1]. Due to this issue, a company's supply chain might be disrupted along the way to accomplish the customers' demand [2]. Quick Response

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Manufacturing (QRM) is found to be an effective strategy for companies to reduce external and internal lead times throughout an organization [3]. QRM is a companywide strategy to cut the lead times in all phases of the supply chain of manufacturing operations. It means that the supply of a faster and quicker product can be completed and at the same time can compete with the rapidly changing manufacturing sector [4]. QRM is an excellent strategy to increase profitability by reducing cost, enhancing delivery performance, and improving quality from the company vision. For a company that works on a make-to-order (MTO) basis of the extensive product variety ranges with variable demand or a company that works on engineering-to-order (ETO); QRM can be an effective strategy for them [5]. Production and materials flow control (PMFC) mechanisms are the capability to respond quickly to highly changing product demand requirements. This is usually not possible with inventory replenishment strategies such as the one implemented by the Toyota Kanban System (TKS) [6]. Paired-Cell Overlapping Loops of Cards with Authorization (POLCA) is a hybrid push-pull PMFC mechanism developed as part of the overall strategy of QRM. According to Suri [9], POLCA is a mechanism that overcomes the limitations of pull systems in high-variety and customization product environments, demonstrating its apparent relevance for the MTO and ETO sectors. On the other hand, Lean Manufacturing (LM) is another practice that focuses on minimizing waste within manufacturing systems while maximizing productivity [4]. In this case, QRM can complement LM in a make-to-order environment [7].

1.1. Introduction of QRM in the automotive industry

Most manufacturing companies endure a tough time adapting to the world economy challenge. In order to supply the customer's requirement on time, a steady supply chain system is required such as the implementation of the Production Material Flow Control (PMFC) mechanism. Combined with the implementation of emergent technologies, it can be of great value for improving the performance and quality of products. Manufacturing is producing products using specific tools, machines, chemical or biological processing. Some manufacturing process is in a sequential flow from one operation to another. It also requires much power or labor to transform raw materials into finished products. The finished products will generate profit to the companies and boost the country's economy.

The quick Response Manufacturing (QRM) method consists of four core concepts: the power of time, organization structure, enterprise-wide application, and system dynamics. Long lead times will significantly increase the labor costs up to five times the costs for work-in-progress (WIP) and the finished products. Rethinking Organization Structure, QRM transforms traditional functional departments into an organization consisting of "QRM Cells". Although the cell concept has been known for some time, QRM Cells are more flexible, holistic, and applied outside the shop floor. Implementing a Unified Strategy Enterprise-wide, QRM is not just a shop floor approach; it is used throughout the enterprise. This includes material planning and control, purchasing and supply chain, quoting, order processing and new product development. QRM provides a single, unifying approach for the entire enterprise. Exploiting the System Dynamics by getting managers to understand how capacity, batch sizes and other factors impact lead times, QRM enables them to make improved decisions that result in shorter lead times.

QRM focuses on reducing lead times throughout all the production supply chain activities of an organization [9]. Externally, QRM means responding to customers' needs by providing quick design and manufacture of products. Internally, it means reducing lead times for all tasks, improving quality, reducing costs and increasing the speed of response. PMFC strategies for QRM must address the need and the capability of firms to respond quickly to profoundly changing product demand requirements [10]. The push systems to control Through Put (TP) by establishing a master production schedule and measuring Work-In-Process (WIP); and pull systems as those control WIP and measure TP against the required demand [11].

The global industry faces increased competition in this industrial field and the need to reduce costs and lead time while improving product quality. These situations are getting challenging due to the market demanding higher quality, greater product variety, lower price, and a small-time interval for the delivery of the products. These could lead to an improper supply chain mechanism; hence, disrupting a company's performance. The assembly line layout should have proper planning to counter the buffer time, especially at the heavy workload stage. The study helps the company detects long lead time elements from the inventory section towards the assembly line, which supposedly has quite a long distance to travel. Thus, the objective of this study is to improve the current line layout of the automotive industry aiming for Just-In-Time by implementing QRM methodology.

2. Supply chain

The supply chain is a network between a company and its suppliers to produce and distribute a specific product to the final buyer. This network includes different activities, people, entities, information, and resources. In other words, the supply chain is the steps of moving and transforming raw materials into finished products, transporting products and distributing them to the end-user. Nowadays, global competition is more complicated for a company to work at a specific due date. Therefore, it is necessary to have a proper supply chain for better industry performance [4]. Three types of supply chain performance metrics involve: time, cost, and quality. It is essential to analyze a company's supply chain and maintain its performance since business competitiveness is notably dependent on supply chain performance [12]. A smooth supply chain is a supply chain that can be responsive, react, and change to meet the changes in market demand, thus defined as Supply Chain Flexibility (SCF). The supply chain has become highly complex and dynamic as customers demand better-customized products. Therefore, a company that matches supply chain flexibility and environmental uncertainty perform better than other company that did not complete the match [13].

2.1 QRM in Supply Chain

People only see QRM as a plan on responding to the customers' needs by rapidly designing and manufacturing products customised to customised requirements. However, QRM is basically to reduce the lead time for all tasks, improve quality, reduce cost and eliminate non-value-added waste within the organization while increasing competitiveness by producing better and faster serving customers. In the attention to save time for production and sale of products, a trend pulled toward a variety of finished products led to inventory, overhead, and efficiency problems. According to Gromova [14], effective supply chain management becomes more complicated when the available supply does not meet the demand. The company that applies the QRM concept manages to reduce the time for developing new products and the time from receiving orders to shipping products by 40-60% while reducing the total cost by 20-30% [14]. While the demand is getting more complex and challenging, the manufacturers still need to reduce the lead time and other waste while maximising productivity. This called for the application of Lean Manufacturing (LM) in QRM. Filho et al. [15] found "Lean Manufacturing (LM) faces several difficulties in dealing with all product types, especially in the wide variety and low-volume production". Therefore, the QRM concept needs to be implemented with LM to achieve better results. When QRM is implemented with LM, lead time estimation has improved with a 22.67% reduction, and the maximal utilisation level was at 74.20% [15].

2.2 Just in time

A just-in-time (JIT) inventory management is a strategy that aligns raw-material orders from suppliers directly with production schedules. JIT manufacturing is also known as Toyota Production System (TPS) because Toyota's manufacturer adopted the system in the 1970s. The JIT aims to minimize inventory and increase the efficiency of a company [14]. The JIT inventory management uses Kanban as a scheduling system to avoid overcapacity of work in process. Implementing JIT inventory management relies on steady production, high-quality artistry, no machine breakdowns, and reliable suppliers. The JIT inventory management will cut or minimize the inventory cost because the manufacturers receive materials and parts needed for production only. This will reduce the storage or inventory cost since there will be less or no unwanted inventory if an order is cancelled or not fulfilled. Kanban scheduling is often used for the JIT inventory management strategy. Japanese scheduling is developed by Taiichi Ohno, an industrial engineer at Toyota. The aim is to improve manufacturing efficiency. The problem areas are highlighted by measuring lead and cycle time across the production process, which helps identify whether the time taken or takt time is efficient for JIT inventory management [15].

3. Automotive manufacturing line

The study has been conducted based on the automotive manufacturing environment located in Malaysia. In the normal production process, the parts and tools from the inventory area will be transported to the production workstations. Due to the enormous distance between inventory and stations might become an obstacle to the production output if the demand from customers are suddenly increased. Once the data from the overall production process is collected, it will be simulated by using the Witness programming software. The main focus is to study the optimized time to produce the parts by implementing Just-in-time (JIT) inventory management.

3.1 Workstation samplings

The research is conducted on the selected production line in the automotive company X, where there are 25 workstations with the specific task for each station. The workstations involved in the study consisting of picking, swap and top up. Each station will have one operator to handle a job, and the time assumed is done by considering the task time for each trolley controlled by an operator. The time taken for each task is different, following the number of trollies used in each station. The takt time is assumed to be the same for all workstations in this production line.

Each station has been given its number of tasks with the number of operators set up as shown in Fig. 1 and Fig. 2. This shows that every station has its cycle and takt time, and each workstation needs to follow the takt time that company X has planned. Any station that exceeds the takt time will automatically delay and affect the next assembly line in the sequence since it is a single line model. Thus, the overall production will be delayed and will increase the cost for this production line.

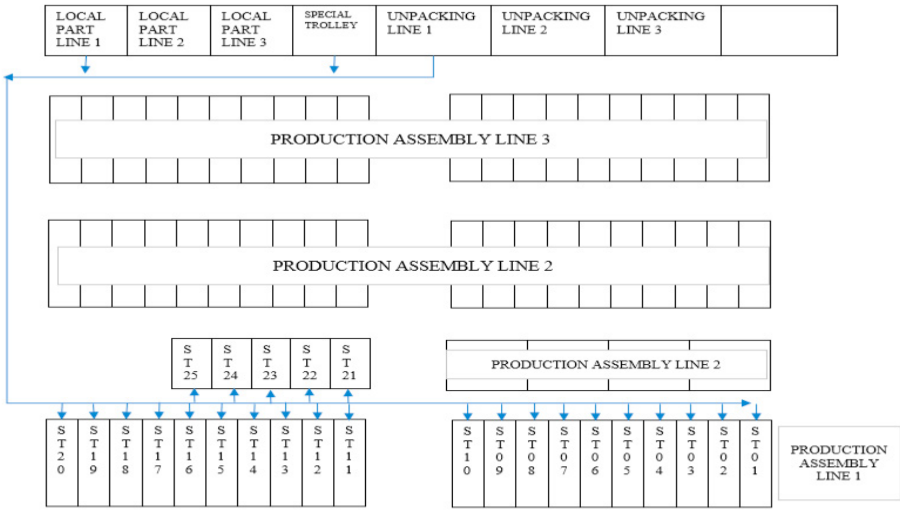


Fig. 1. The layout of the production Assembly. There have 3 assembly line in this production.

Process	**1 Operator**	**2 Operators**
Takt Time picking (Min)	2	1
Takt Time swap (Min)	2	1
Takt Time Topup (Min)	3	1.5
Takt Time Transport (Min/cycle)	3	NA

Takt time Assumption	**Working Hours (min)**	**Demand of output (unit)**	**Cycle time (Min/cycle)**
Takt time	450	25	18

Fig. 2. The data of the time study

Table 1. Time study for the selected production line

Station	*Process Quantity*			*Process Time*				*Minute*
	Picking	*Swap*	*Top*	*Picking*	*Swap*	*Top*	*Transport*	*Total Time*
ST01	*2*	*2*	*0*	*4*	*4*	*0*	*3*	*11*
ST02	*4*	*1*	*3*	*8*	*2*	*9*	*3*	*22*
ST03	*4*	*2*	*2*	*8*	*4*	*6*	*3*	*21*
ST04	*4*	*1*	*3*	*8*	*2*	*9*	*3*	*22*
ST05	*2*	*2*	*0*	*4*	*4*	*0*	*3*	*11*
ST06	*2*	*2*	*0*	*4*	*4*	*0*	*3*	*11*
ST07	*4*	*1*	*3*	*8*	*2*	*9*	*3*	*22*
ST08	*5*	*5*	*0*	*10*	*10*	*0*	*3*	*23*
ST09	*5*	*3*	*2*	*10*	*6*	*6*	*3*	*25*
ST10	*5*	*3*	*2*	*10*	*6*	*6*	*3*	*25*
ST11	*4*	*2*	*2*	*8*	*4*	*6*	*3*	*21*
ST12	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
ST13	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
ST14	*2*	*2*	*0*	*4*	*4*	*0*	*3*	*11*
ST15	*3*	*1*	*2*	*6*	*2*	*6*	*3*	*17*
ST16	*5*	*3*	*2*	*10*	*6*	*6*	*3*	*25*
ST21	*1*	*1*	*0*	*2*	*2*	*0*	*3*	*7*
ST17	*7*	*3*	*4*	*14*	*6*	*12*	*3*	*35*
ST18	*3*	*3*	*0*	*6*	*6*	*0*	*3*	*15*
ST19	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
ST120	*3*	*3*	*0*	*6*	*6*	*0*	*3*	*15*
ST22	*5*	*5*	*0*	*10*	*10*	*0*	*3*	*23*
ST23	*4*	*2*	*2*	*8*	*4*	*6*	*3*	*21*
ST24	*5*	*1*	*4*	*10*	*2*	*12*	*3*	*27*
ST24	*4*	*4*	*0*	*8*	*8*	*0*	*3*	*19*
ST25	*4*	*0*	*4*	*8*	*0*	*12*	*5*	*25*

From Table 1, it is shown that there are a few stations that exceed the takt time assumed 18 min as shown in figure 2, which can cause a buffer time in the production line. Hence, it can affect the lead time for this production line. The takt time that the company has assumed is made to achieve its daily target output.

4. Results and Discussion

The production line lead time is affected by each workstation's idle and busy time. Buggies are inter-connected in supplying the parts, which at the same time can reduce the number of buggies used in the production line. Based on the scenario, a Witness simulation of the current layout is done. The bar chart of the simulations are shown in Fig. 3.

Fig. 3. The bar chart of the simulation data

Based on Fig.3, many stations have idle time of more than 50%. This is because the data shown by the simulation is according to the task in each station, not by the whole workstation. However, several stations took more than 20 minutes to finish their production tasks. The higher takt time in a station can lead to a blockage in the production line.

4.1 Improvement by splitting the production line

The line layout has been reviewed again to reduce the operation time for the overall workstations. The current line layout takes too long for the production line to finish its task. It is not good because when the order or demand increases, they need to make a lot of production in a shorter time, leading to blockage or bottleneck. Therefore, the improvement is made by splitting the production line into two sides: the left-handed line and the right-handed line as shown in Fig. 4. Each line gets its trollies from the same inventory and is carried in different lines simultaneously, with the addition of an operator to speed up the process. With this improved data, no stations have a processing time exceeding the takt time assumed, which is 20 minutes.

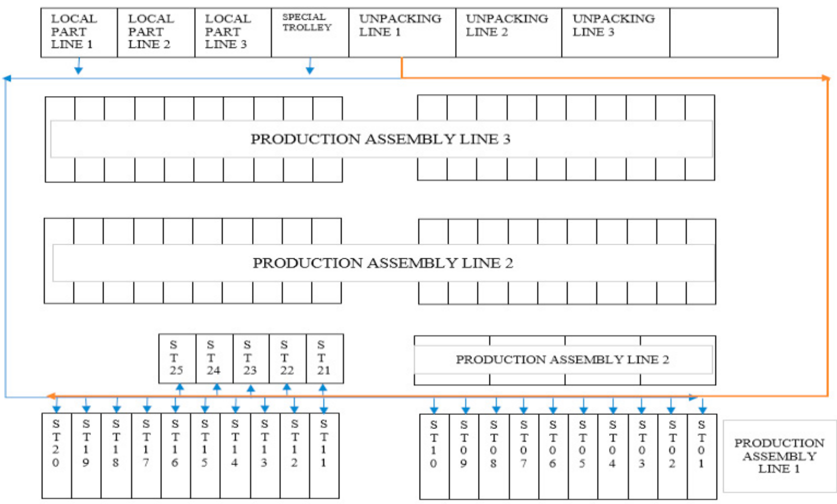


Fig. 4(a) The improved line layout of the production line

Fig. 5. The bar graph of the improved simulation data

The graph in Fig. 5. shows positive feedback since there are stations that offer lower idle time. Even though having a high idle time is not suitable for the company's productivity, however, there is also an advantage to having high idle time. By implementing JIT, having high idle time means that the company is ready for a better supply chain scheduling during the busy hour when the demand is high.

4.2 Discussion

The data has been compared between the current layout and the proposed improved layout, which determines the suitability of the JIT inventory management implementation.

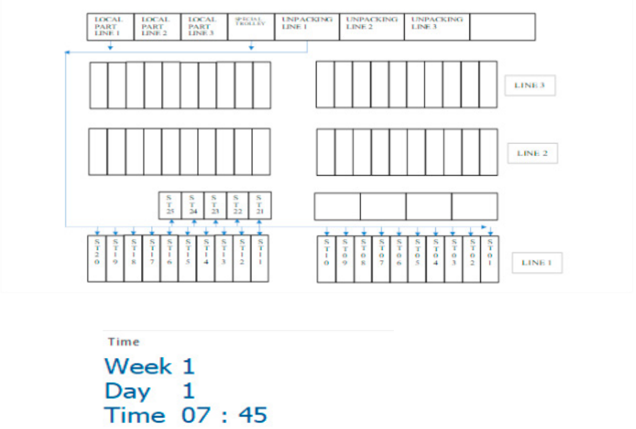
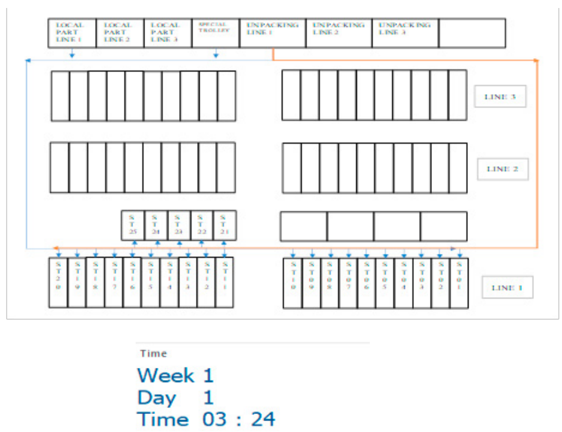
Current layout	Improve layout
	

Fig. 6. The comparison between current and improved layout

Fig.6. shows a vast difference in the time taken for the overall process in the production line layout between the current design and the improved structure. In implementing the JIT inventory management, it is essential to have a short process time in the production line. This is because JIT is the management where the material has only been processed or manufactured when the order is received, which reduces the inventory cost or inventory holding. By having a short process time, the company can work with high productivity without worrying too much about blockage during the busy hour or high demand periods, since the idle time is increased in each station due to the short process time in the long takt time period. Therefore, in the busy hour, the idle time can be changed into a busy time where the employee will do extra work, but still within the takt time, which will not affect the company's lead time. The improvement of overall process time is shown below.

$$\frac{actual\ time - improved\ time}{actual\ time} \times 100\%$$

$$\frac{465\ \text{min} - 337min}{465min} \times 100\% = 27.5\%$$

The improvement of the time taken for the overall production process is hugely affected by splitting the production line.

Table 2. Comparison task time between current layout and improved layout

Process	LH time is taken (min)	RH time is taken (min)	current time is taken (min)
picking	46	42	176
swap	24	28	108
Top-up	33	21	102
transport	70	73	79
Total	173	164 (337)	(465)

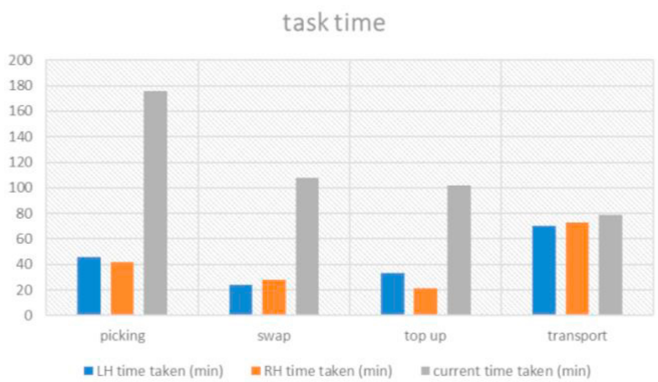


Fig. 7. The bar chart comparison between current and improved time

As shown in Table. 2. and Fig. 7, the time taken for the tasks has been reduced significantly. The current layout took 7 hours 45 minutes, while the improved design only took 3 hours 24 minutes; this is due to the splitting line that works simultaneously. This considerable reduction is an indication that the company is ready to apply the JIT inventory management, which can help them reduces the inventory cost, decrease waste and increase the efficiency of the production line.

5.0 Conclusion

This research aims to analyze the problem in the current layout of the automotive company X and propose an improved design aiming for the JIT inventory management strategy. The simulation has been done for the current set-up, where there is a less busy time with high idle time and long process time in the production line. The long production time is a problem where improvement needs to be done. The layout has been improved by splitting the production line and proven successful by the Witness simulation results. The overall process time taken has been reduced significantly, and the improvement has been made by 27.5%. By having a shorter process time with a high busy time, the company is ready to implement the JIT inventory management by improving the current layout.

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