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TOOL FOR MAPPING MANUFACTURING CRTICAL-PATH TIME IN JOB SHOP ENVIRONMENT

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ABSTRACT : *Today, manufacturing companies are adopting new production paradigm of mass customization to meet their customers' future demands and to survive in an intensely competitive marketplace. However, mass customization manufacturing requires a high degree of flexibility to deliver customers' orders on time. Lean manufacturing is one of the commonly employed philosophies in industries. However, not all manufacturing system is compatible with the approaches of lean. Quick Response Manufacturing (QRM) has emerged as an alternative strategy for a high mix and low volume production environment. QRM is a company-wide strategy with the key aspect of reduction in lead time. This study was conducted in a case company with a job shop production system. The company, making highly engineered products with variable demands, is confronted with the main challenge of consistently long lead times leading to poor on-time delivery performance to their customers. To mitigate this problem, a tool for mapping the manufacturing critical-path time (MCT) is developed based on the current situation of the company. The output of this tool provides information on lead time and presents a visual indicator for the manufacturing critical-path time of a selected major product family.*

KEYWORDS: High mix low volume environment, Quick Response Manufacturing (QRM), manufacturing critical-path time (MCT)

1.0 INTRODUCTION

Lean manufacturing as exemplified by the Toyota Production System is characterized by a low mix high volume environment. As the degree of product customization increases, the application of lean principles to ensure smooth production flow becomes a major challenge. This study employs QRM as an alternative way for a high mix low volume production environment. Job shop is categorized as high mix low volume manufacturing system due to different process routes and process time for each of the products, coupled with low volume of demand from customers. In brief, QRM is a concept which reduces manufacturing critical path time (MCT) simultaneously across enterprise, and it is best applied in the high mix low volume environment. This competitive strategy is also suitable to work on make-to-order (MTO) and engineering-to-order (ETO) environments.

This study is conducted in a case company which produces high precision tools, die moulds, puncher and other products in a job shop environment. Over the past few years, On-Time Delivery has often been the challenge to the company. Apparently, MCT needs to be effectively monitored and controlled by a MCT tool in order to remain competitive and reduce MCT. For the purpose of this study, one major product family is chosen. This major product family is determined by the volume of sales. The demand and cycle time data for the selected product are based on historical data collected from the company. Currently, Enterprise Resource Planning (ERP) systems are implemented to record the lead time for all the product families. However, the company wish to fully utilize the available information of the ERP system by using the developed MCT tool. This MCT tool will use to map and show the performance of all the product families. Through the output of the MCT tool, the company is able to determine the area of the problem and MCT can be reduced by incorporating with the QRM principles and other philosophy of production and planning control.

This paper is organized as follow. Section 2 provides a literature review of the related subject. In section 3, the details for the model development is presented. This is followed by the result and discussion of MCT Tool in section 4. Finally in section 5, conclusion and future research opportunities will be discussed.

2.0 LITERATURE REVIEW

Lean manufacturing is derived mostly from the Toyota Production System (TPS) [1]. Lean manufacturing is also known as lean production and just-in-time (JIT) [2]. Womack and Jones [3] outlined five lean principles important for a successful lean implementation. The basic concept of lean is the systematic elimination of *muda* through eliminating non-value added waste, resulting in improved quality, reducing costs and reducing lead times [4]. From the point of view of the customer, the aim of lean production is simultaneously transforming waste into value [5]. The main objective of lean is to minimize variability of supply, demand and processing, leading to the elimination of waste [6].

The Toyota production system works best for low variety and high volume environment [7]. The core tools employed are Takt times and level scheduling. These tools have been used to eliminate variability in operations [8]. However kanban and heijuka are not manageable in the case of products of high mix and low volume environment, where machine cells cannot be devoted to a specific product; thus, complex scheduling techniques are required [7]. Lean principle, such as JIT and production leveling is also a challenge to implement to high-level mass customization and high variety production environment [9] [10]. Although many companies are willing to apply lean manufacturing, the way of creating a lean success trajectory is a difficult process. One of the difficulties is that each lean implementation is unique [11]. Statistically, there are only about 2 percent of companies that has fully achieved lean transformation [12].

On the other hand, QRM is a philosophy, introduced by Professor Rajan Suri from University of Wisconsin, is a company-wide strategy that pursues the reduction of lead time continuously in all aspects of a company's operation. It is an extent of time-based competition philosophy. Specifically, it is useful to define QRM into two contexts: namely, the external and internal. From the customer's point of view, the external aspect of QRM means a quick response to customer's changes, whereas, internally means QRM focuses on reducing lead time for all tasks in a company. The overall effect will result in improved quality, lower cost, and of course, quick response [4]. QRM is a concept which builds on JIT and lean principles of waste reduction and integrates lead time reduction as the driving strategy [13]. The four core concepts of QRM are realizing the power of time, rethinking organizational structure, understanding and exploiting system dynamics, and implementing a unified strategy enterprise wide [8].

Figure 1 provides a comparison between Lean and QRM on key production characteristics. Lean fits very well in the environment of low mix, high volume, low degree of customization and low variability. On the other hand, QRM is designed for systems whose key characteristic fall to the right continuum [14].

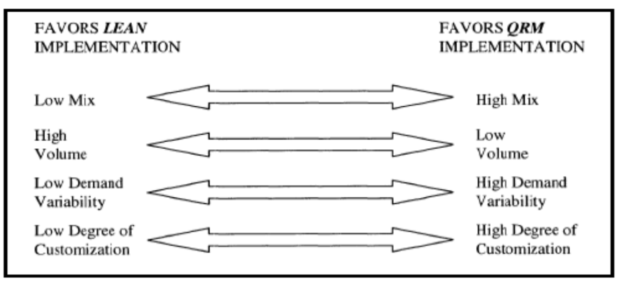

Figure 1: Key Production Characteristic Continuum [14].

The definition of lead time is integral to the theme of QRM. The traditional definition of lead time is defined as the time from when an order is transmitted by a customer until the order is received by that customer. It does not give any indication of how order fulfilment is achieved. In other words, it only focuses on the end result [15]. However, MCT is a lead time indicator that shows both the outcome and how the outcome is achieved [16]. A fundamental meaning of MCT is the typical amount of calendar time from when a customer creates an order: Through the critical-path and until the first piece of that order is delivered to the customer [8]. The MCT is the lead time metric for QRM implementation [15]. MCT Maps are simple. They present time proportionally, show various paths clearly, and visually highlight the major contributors from the overall timeline. In comparison to Value Stream Map, the MCT Maps have clear targets of improvement, and it identifies with one single parameter only [8].

In conclusion, QRM is a suitable approach for the job shop environment, and it is more appropriate than the Lean approach. To increase flexibility and organization's responsiveness, QRM is a better strategy than the others. Indeed, to achieve these objectives, a tool used to map MCT plays an important role to improve the overall performance of the company. Nonetheless, there is a lack of published case studies on the application MCT and QRM tools. As a result, the development of MCT mapping tool for a local small medium enterprise component manufacturer is presented.

3.0 MODEL DEVELOPMENT

Lead time is an important metric in any manufacturing industry. Most industries wish to have short lead time and always provide on-time delivery to customers. To achieve this goal, a tool to map MCT will be useful as it can graphically represent time proportionally, by indicating the various paths clearly and visually highlight the major contributors from the overall timeline. This MCT tool also helps the manufacturers to forecast on the working days needed for a future job.

Figure 2 shows the methodology of MCT Tool development. The initial part of the development process, that is identifying focus target market segment (FTMS), is illustrated in Figure 2(a). FTMS is commonly defined as the market which a company wishes to focus, and it is determined based on the customers demand volume [8]. The quantity of a job from the historical data represents the customer demand volume. This serves as the input data, sorted into product name and quantity by using the Microsoft Excel's pivot table. From the sorted data, FTMS is determined based on the customers' demand volume. A sample output for FTMS is discussed in the next section.

Once the FTMS is identified, the MCT Tool is developed as shown by the flowchart in Figure 2(b). First, the FTMS data is downloaded from the ERP system of the case company. The FTMS data will next be manually inspected and validated. Then, the input data will be used to calculate the pre-processing time, post-processing time and processing time. These calculated data will be then tabulated via a designed user form GUI. In addition, the information on the number of jobs involved with inventory (where partial or completed products in store) and the number of days needed to make finished goods are recorded in the system. This is followed by the calculation of the average MCT per job and the number of days required for inventory stock. Next, the sequence number for each of the process is recorded. The process will be sorted according to the sequence. Lastly, the MCT bar chart is generated. From this chart, the Total MCT, touch-time and untouched time will be displayed. In context, the total MCT includes the processing time, pre-processing time and post-processing time. The touch-time includes only processing time; and the non-touch time includes pre-processing time and post-processing time.

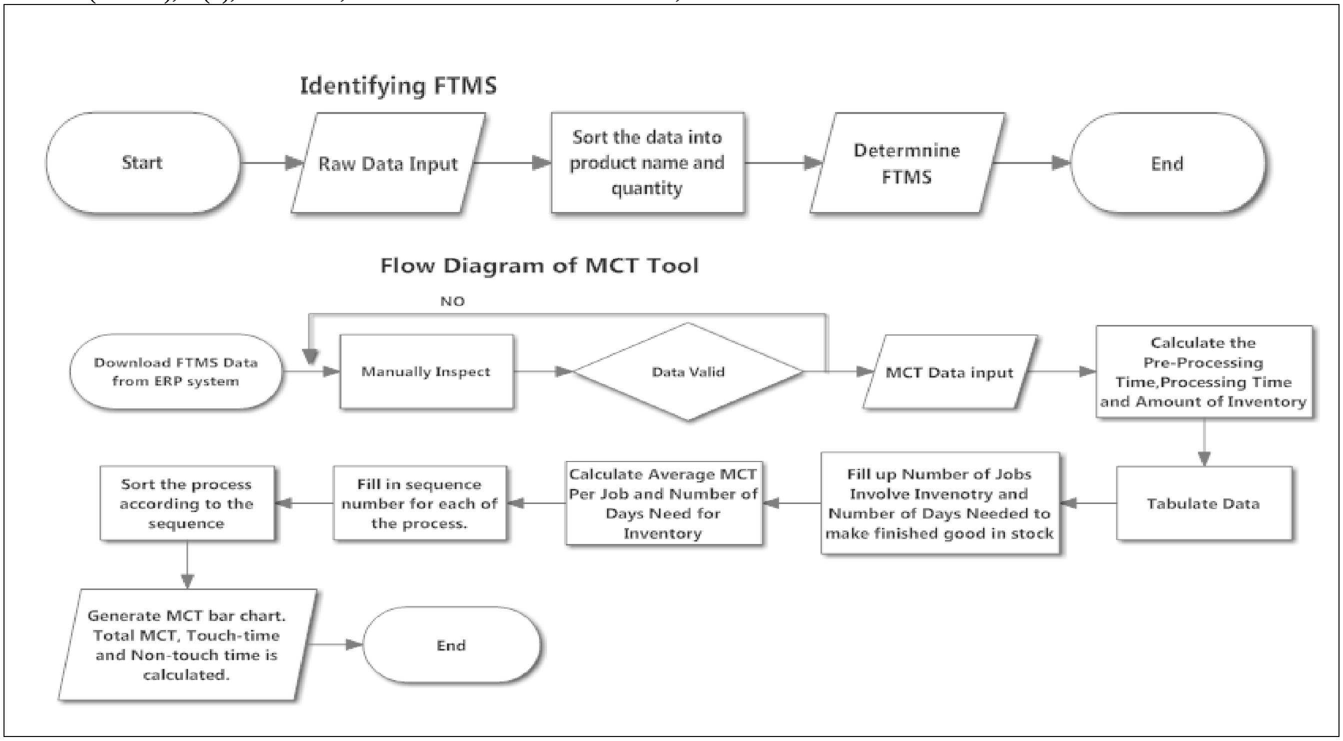

Figure 2: Methodology of MCT Tool Development. 2(a) Identifying and FTMS 2(b) Flow Diagram of MCT Tool

4.0 RESULTS AND DISCUSSION

This section presents the sample ouputs and discussion for the developed MCT tool. Firstly, FTMS was chosen based on the quantity order by the customers as mentioned on the previous section. The higher the quantity ordered by the customers, the higher the score in the "Total" column, as shown in the example in Figure 3a. Therefore, the highest score in "Total" column will be chosen to be the FTMS. However, in this case, the shaft was the second highest score, as shown in Figure a. It was chosen to be the FTMS instead of the highest score product. The highest score product "SAUGERNIPPEL 6 LANG" was not chosen because most of the processes were outsourcing process. As a result, most of the time were taken by the subcontractor. For product "Shaft", the processes were completed within the company.

2		
3	Sum of True Quantity	
4	Description	Total
5	SAUGERNIPPEL 6 LANG	977
6	SHAFT	397
7	TOOL HOLDER PANEL	304

Figure 3a: FTMS is identified.

After identifying shaft as the FTMS, its corresponding MCT was calculated and mapped by using the developed MCT Tool. Figure 3b shows that the FTMS data were calculated into four categories: processing time, pre-processing time, post-processing time and number of inventories. Figure 3c and 3d show the tabulated data and the analysis of MCT for each job. In this study, since each job is represented by a specific customer order, and the goal was to reduce lead time for orders, hence measuring MCT by job is considered appropriate. On the other hand, if these parts were being made to stock and individual pieces were sent to customers later, then weighting the MCT by piece would be a better option.

Figure 4 shows the "MCT Total" result, which was a total of 22.88 days. The touch time had the percentage of 66.94% and the non- touch time had the percentage of 33.06%. This result included the time required to manufacture the semi-finished product or ready product taken from inventory. These are the extra stock left from the previous similar orders. On the other hand, the MCT tool is also capable of mapping the actual MCT time. As shown in Figure 5, the actual MCT time indicated a total of 22.38 days. This does not consider the time to manufacture the stock from inventory. The MCT Total and MCT Actual bar charts clearly map the processes and time it takes to fulfill an order. The charts also highlight opportunities for improvements by quantifying the longest critical path, the touch and the non-touch time activities. In our example, the turning process (represented as "NCL" process) was the critical-path and this process took a total of 12.95 days. This implied a clear target for improvement by the planner.

Calculation	Processing Time	Pre-processing Time	Post-processing Time	Inventory
454.74	454.74			
24.71	24.71			
0.51	0.51			
140.75	140.75			

Figure 3b: Calculation step of FTMS data which calculated into Processing Time, Pre-processing time, Post-processing time and number of inventory.

	Resource	Data
	ASB	
Job Order	Sum of Pre-processing	Sum of Pr
J/1302-00465 / FS 1302038		
J/1304-00680 / FS 1304015		
J/1401-00141 / FS 1401031 (1/2)		
J/1401-00141 / FS 1401031 (2/2)		
J/1402-00237 / FS 1402038		
J/1402-00735 / FS 1402090		
Grand Total		
Count		
Average MCT Per Job		
Average MCT Per Job(Days)		

Figure 3c : Calculation steps of Average MCT per Job (Days)

Sum of Inventory	
Job Order	**Total**
J/1302-00465 / FS 1302038	
J/1304-00680 / FS 1304015	
J/1401-00141 / FS 1401031 (1/2)	
J/1401-00141 / FS 1401031 (2/2)	1
J/1402-00237 / FS 1402038	
J/1402-00735 / FS 1402090	
Grand Total	**1**
Number of Jobs	1
Amount of Inventory per job	1.00
Unit/day	2
Number of days Needed for inventc	0.5

Figure 3d: Calculation steps for Number of days Needed for Inventory was calculated.

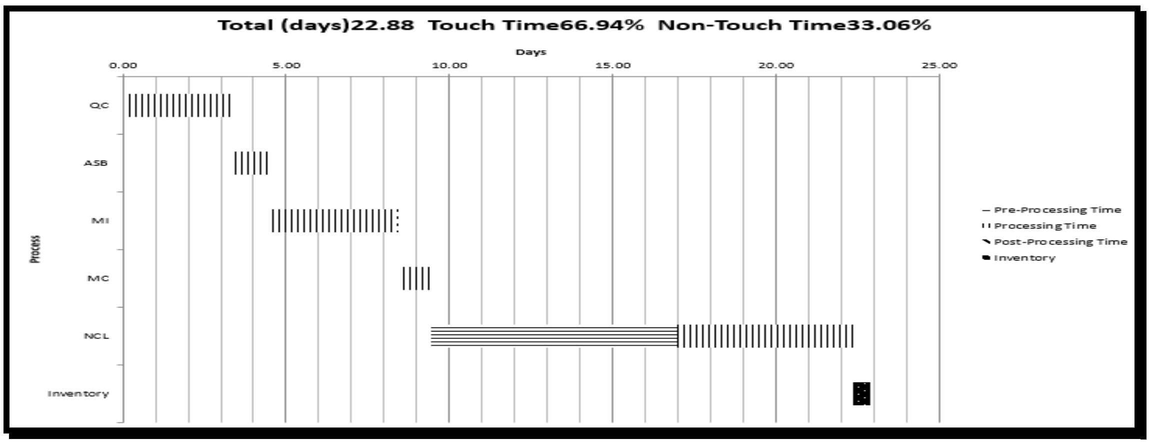

Figure 4: MCT Total bar chart.

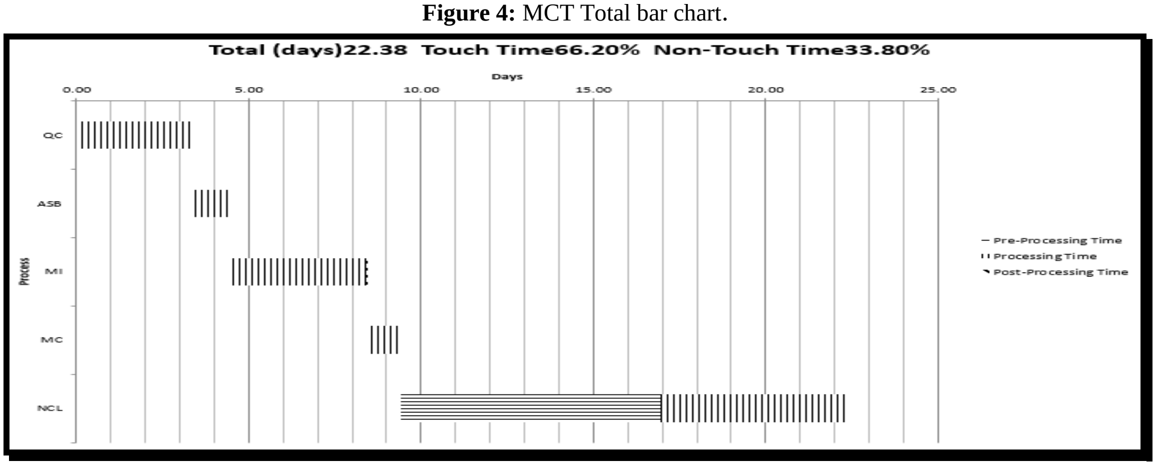

Figure 5: MCT Actual bar chart.

5.0 CONCLUSION

MCT is the main performance metric in the implementation of QRM. A MCT Tool was developed based on the real world data collected from the case company. Results show that this tool is useful for the company to map the processes and analyse the MCT of a product; hence, providing accurate indicators for determining performance improvements. The next level of this study will be to integrate the MCT Tool with the other QRM tools, such as the POLCA and virtual cell for the purpose of improving production flow mechanism for a job shop environment.

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