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Simulation Model Development for Determination of Components Production Quantity and Lead Time Reduction in Mass Customisation of Single Production Stage

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Abstract. Market rivalry forces manufacturing companies to be customer focus and have an agile system. In manufacturing companies that produce semi-common products based on customer order, the pressure from customers are usually faster delivery, reasonable price and higher product variability. This paper presents the use of Mass Customisation (MC) concept in order to cope with faster delivery and higher product variability. The MC concept is realised by determining Customer Order Decoupling Point (CODP). Besides MC, Theory of Constraint (TOC) concept is also applied in order to address problem that may occurred after MC implementation. Based on a simulation analysis, it shows that CODP implementation could improve delivery lead time and product variability performance dramatically up to 5.15 times compared to existing system. An optimisation algorithm is also proposed for further study in order to improve cost performance of the products.
Keywords: Mass customization, simulation model, lead time reduction, CODP, TOC.

1. Introduction
Market rivalry has forced manufacturing systems to focus on customer satisfaction as one of their important objectives. It has been realised that several big manufacturing companies are not able to survive due to their fail in satisfying the customers. With globalization and pressure from customers for faster delivery, reasonable price, and higher product variability, it is expected that manufacturing companies strive for a more effective and efficient production. Thus, there are often happened a tradeoff between cost and other performances when efficiency is strived for [1]

In a production system, there are production planning and control activities arranged based on customer demand. This is one of operational strategic that applied by company to satisfying the customer. One of the outstanding results in production planning that could satisfy the customer is by improving the inventory control system especially in Make to Stock (MTS) to Make to Order (MTO). According to [2] inventory control is the act of maintaining the inventory at a reasonable level that could fulfill customer's demand in terms of date and amount, which leads for minimizing total costs and maximizing profit.

[3] stated that MTS production system is based on forecasts of product demands and production is triggered without taking into account customer orders. Hence, considerable holding costs or stock-out costs are inevitable in a context of highly fluctuating demands. According to [4], in MTO

environment, the production process begins only after orders are received from the customers. In some cases, the company used this method to reduce inventory because the product orders are known in advance. However, the MTO company requires longer delivery lead time due to materials preparation and late production starting time. Hence, based on the complexity which happened in MTO and MTS company, a potential paradigm called Mass Customization (MC) could be proposed to address the complexity.

Elaborated company in this study is a company produces especially hospital equipments and other minor products. This company is still struggling to fulfil customer satisfaction in term of shorter delivery lead time and optimum production quantity. The problem was occurred due to there is a shared production machine to produce several components and that machine then become a bottleneck machine. Objective of this study is to develop a simulation model to determine optimum production quantity with shorter delivery lead time. A simulation model is proposed due to very complicated process in the production system.

Problem identification was carried out by implementing well known theory called Theory of Constraint (TOC). The shared production machine causes blocked process, and after the blocked process could be identified, then Mass Customisation (MC) concept was applied by determining Customer Order Decoupling Point (CODP). Identifying CODP is to know the position of stock and order which has purpose to reduce the delivery lead time to customers and increase the manufacturing efficiency by optimising the bottleneck machine [5].

2. Related Works
There are several previous studies that are much related to Mass Customisation (MC) study. [6] stated that in an electronics industry company, the concept of MC could be used to gain higher improvements in the efficiency and performance. In the concept of MC which concern on a module-based product range and the use of product configuration systems for sales and order processing, the company record shown that American Power Conversion (APC) did a mass production of the standard components and fulfil the customer orders based on the final assembly. By implemented the concept of MC, the whole delivery time for a complete system could be reduced from 400 to 16 days. It also influences the production cost that significantly reduced.

[7] explained about timing games and Flexible Manufacturing System (FMS) using barbell model with continuous time and make a repetition for purchasing to identify the product differentiation and production flexibility affect firms' timing of order entry. That study focuses on the maximum differentiation in product location and minimum timing differentiation as the outcomes. The result of that research is there is no market failure in the product location choices but there were lateness and the earlier entry could be classified as flexible production system. Otherwise, there also lateness entry which can be classified as less flexible production system.

TOC usually concern in high restricted contribution margin, reducing inventories and operating expenses. Hence, profitability could be improved efficiently. A study showed that TOC could be implemented in a furniture company by identifying the bottleneck or capacity constraint. Then, the constraint could be explored effectively and it increased up to 42% of company throughput [8].

Another study has been carried out in a garment industry that concerns on the MC that integrated with custom-made goods on a mass scale with good quality, low price and high productivity. In that study, there is a need to respond the customers' demand quickly and could be categorised in which product that could be customised and could be reached in very short time. Because of the fluctuating demand, there is a need quick respond to market that leads to the lead time to be shorter. In that industry distribution network, it has three tiers that consist of customers, three logistics service providers and factories. Based on those tiers, customers were categorised as end customer and the third logistic service providers and the company were categorised as the upstream for manufacturers. Thus, it could be concluded that the half-finished products are produced with mass production method with very low cost. Besides that, the product modules to be produced for customised products are based on the customised data [9].

[10] explained that the variety of customer needs and wants forced the manufacture to be agile. The variety of product must be high with short delivery time. Thus, this situation forces the company to combine among the order based and stock based with high flexibility and short manufacturing lead time using an MC concept. According to that study, the company was able to reduce the manufacturing lead time from 43 days to 24 days when producing higher product variety. In the analysis, that study was using product picture analysis to classified the basic components of every product, customised components and required manufacturing process. Operation process chart (OPC) was also required for MC analysis. That study also proposed for future study to apply an optimisation algorithm to control the inventory amount and set up time before CODP manufacturing process.

Thus, based on the previous studies, this study would conduct the analysis of MC among the components that should be produce first. After MC analysis by identifying the CODP, then a simulation model was developed to do further analysis to optimise the production quantity. A simulation software called FlexSim6 was used to develop the simulation model.

3. Analysis Method
Data collection was carried out using observation and interview. The observation applied direct observation to know the production process flow and to collect quantitative secondary data. The interview was also carried out by interviewed the production manager and Production Planning and Inventory Control (PPIC) staffs. Data processing was carried out in several stages which are:

3.1. *Product structure analysis*
There are 4 main products considered in this study. The 4 main products have higher demand from customer and therefore could be used as the basis of the product analysis. The first step in this study was analysing the products designs in detail in order to find components that actually could be considered as common components.

3.2. *Product process analysis*
This stage was carried out based on operation and routing sheet. It resulted that the required machines and their processing time to make every component could be identified. Besides that, production layout was also need to be identified in order to know exactly position of every machine in the production shop floor. Rich Picture Diagram (RPD) was used to depict the production process flow on the real machines position.

3.3. *TOC*
In this study, TOC was used to identify existence of blocked or bottleneck machine which can cause the longest processing time during components production. TOC was also used as the basis of buffer size determination to keep the bottleneck machine works efficiently.

3.4. *Simulation model development*
Due to complexity of the manufacturing system, it will be more effective and efficient when analysis is carried out based on a simulation model. Development of the manufacturing system simulation was carried out based on the production layout and Operation Process Chart (OPC). The simulation model would be confirmed with the real manufacturing system based on two parameters which are the production quantity and the production lead time. The valid simulation model would then be used to do manipulation to improve performance of the both parameters.

3.5. *Identification of CODP*
In this stage, an analysis based on MC was carried out in order to determine the CODP. First, all of the products would be disassembled in order to analyse the uniformity of the required components based on their production process. In determining the CODP, there is a trade off between MTS concept that is started from raw materials and MTO concept that is close to end products. The CODP is determined

by pushing it forward to be closer to end product to increase mass production level and pushing it backward from end product to be closer to raw materials to increase product flexibility. After the CODP is determined, then the bottleneck machine must be exploited effectively by applying TOC. Bottleneck machine protection could be carried out by providing buffer in front of it to keep it works effectively. The number of buffer was determined based on several simulation scenarios.

3.6. Improvement Verification

CODP would be used as the reference point to manage the production system. MTS concept would be implemented from raw materials to CODP and MTO concept would be implemented from CODP to end products. However, before implementation, verification is required and the simulation model could be used as the experiment object.

3.7. Identification of Lead Time Reduction

After improvement verification and improvements could be seen visually from the simulation model, and then new production lead time based on CODP implementation could be estimated based on the new production quantity.

4. Result and Discussion

4.1. CODP Implementation

In this study, according to product structure and product process analysis which be used as the basis to identify CODP position, there are 62 components that should be analysed. Analysing all of the components lead to ineffective analysis and the result might be infeasible. Hence, a critical component that has highest uniformity and longest processing time was considered as the basis of analysis. The component is called RawMat17. CODP position based on the RawMat17 is shown in Figure 1.
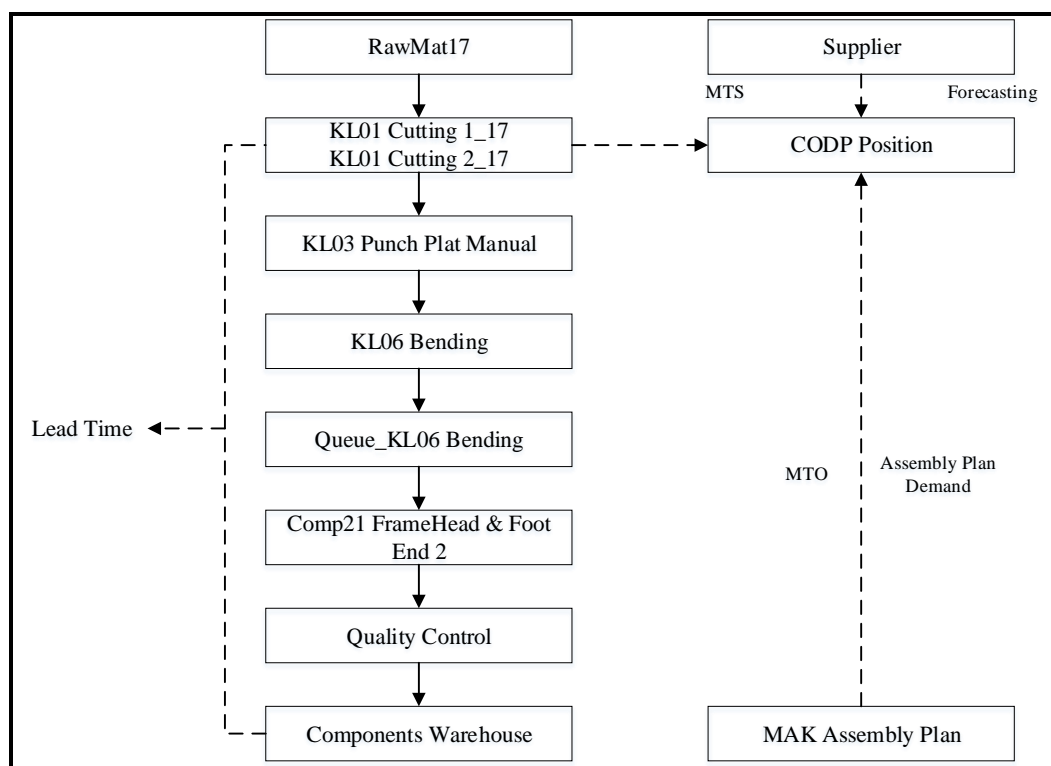

Figure 1. CODP Position based on RawMat17

There are 2 common sub-components required by the investigated component, which are Comp20 and Comp21. In this study, based on production process analysis, there are two potential CODP in the production system, which are at the cutting process carried out by machine KL01 (cutting CODP) and at the Quality Control (QC CODP) process. In order to know the best result, then the simulation system was executed based on cutting CODP and QC CODP. The simulation result shows that QC CODP has superior performance in production quantity. Table 1 shows the comparison of cutting and QC CODP.

Table 1. Summary Simulation Report

No	Simulation Model Development for	CODP Position (Cutting Section)	Improvement (pieces)		Components Warehouse
			Comp20	Comp21	
1	Existing System	-	43	11	336
2	Cutting CODP	KL01 Cutting	36	112	334
3	QC CODP	Quality Control	36	112	1732

Based on the simulation study, it shows that CODP implementation could increase manufacturing lead time and product variety dramatically. However, there is some potentiality to have high amount of components inventory in before-CODP manufacturing processes. Besides that, reduction of set-up time is also considerable to improve performance of manufacturing lead time. For further study, it is recommended to apply an optimisation algorithm to control the inventory amount and set-up time reduction analysis in before-CODP manufacturing processes.

4.2. Lead Time Reduction
It is very hard calculate production lead time in a simulation due to dynamics that have been simulated in the system. However, with referring to Table 1, the component warehouse could be used as the basis to estimate the production lead time. When QC CODP is proposed then the output could increase dramatically 5.15 times than the existing production system. It is reasonable because when the CODP is at the QC point, means that the company could produce the components even though customer order still has not received. The analysis is also show that the difference between products in the investigated company is not much. Customisation could be conducted after QC point and it takes very short time.

5. Conclusion
Based on explanation above, it could be concluded that MC concept is very potential to be implemented to improve delivery lead time and production quantity performance. By implementing CODP, the production system could be managed based on MTS and MTO environment. However, in the MTS sub-system, process block could occur due to a bottleneck machine. TOC could be implemented in order to exploit the bottleneck machine effectively. An optimisation algorithm to control inventory units is also could be implemented to improve cost performance of the production system.

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