MANAGEMENT OF MASS CUSTOMIZED ORDERS USING FLEXIBLE SCHEDULES TO MINIMIZE DELIVERY TIMES

Pandian R.S, Soltysova Z.*

Abstract: The goal of mass customization is to make the products and / or services to satisfy individual customer who makes the order with a specific design for their needs. In real situation it is not so easy deal to meet individual design and to satisfy each customer separately; there is a need to accustom such environment to fulfill the market demand. In such situation, the decision makers are to ensure that they are following flexibility while taking orders and also dispatching them to the customers. One such idea is being developed in this research work. The main aim of this research work is to offer the procedure; flexible mass customization (FLMACUS) to make flexible schedules that meets the customer requirements. A simple heuristics is used to develop the procedure and Gantt charts are used for accommodating the jobs for meeting specific due dates. In this paper batch type Original Equipment Manufacturers (OEMs) are considered for our study purpose. The results from Gantt charts in various categories are depicted. Such types of Gantt charts are hardly found in earlier studies and the results show that this procedure (FLMACUS) is promising in nature to meet customer demands and due dates in a mass customized environment.

Key words: makespan, mass customization, scheduling, batch sizing

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Introduction

The latest industrial development – Industry 4.0 connects various aspects of the manufacturing processes (Ślusarczyk, 2018) and pushes manufacturers to deliver more value through better understanding of demand and respecting individual customer needs. Ghobakhloo (2018) presented a systematic and content-centric review of literature based on a six-stage approach to identify key design principles and technology trends of Industry 4.0. In a mass customization studies, the products and services that are being produced and to be serviced to various customers with individual customer needs and satisfaction in required batches and correct time will make the industries in a competitive edge. To make mass customization profitable, manufacturers need to maximize their effectiveness and flexibility through all possible ways. Especially, flexible schedules play in this order important role by organizing jobs to ensure their minimum flow times (Dima et al., 2010). To make such schedules for an industry is still a promising one. Therefore, scheduling tools might by supported by manufacturing information

* **Sudhakara R. Pandian,** PhD, SACS MAVMM Engineering College, India; **Zuzana Soltysova,** PhD,Technical University of Kosice, Slovakia
✉Corresponding author: sudhame@gmail.com

systems, such as MES to be easily interfaced with the factory site (Modrak and Mandulak, 2009). Then, such approaches enable production to be able to operate without human intervention and maintain production flow between suppliers and customers. There is a lack of literature studies that deal with mass customized product scheduling with suitable Gantt charts presentation. In our approach we consider flexibility in making schedules for various customers' orders with different types of products and with few changes in models of each type. Appropriate Gantt charts are depicted to reflect the results of such flexibility in mass customized production scheduling in batch type industries. The quantity of each model will be demanded certain amount by the customers and subjected to deliver to different locations for further processing of the products. The customers will be satisfied with meeting due dates of their delivery.

Survey of Literature

There are many approaches found in literature for scheduling of job shop and flow shop. Here are few approaches given that deal with scheduling with batches. Aloulou et al. (2014) considered the two-machine flow-shop serialbatching scheduling problem where the machines have a limited capacity in terms of the number of jobs. Terekhov et al. (2014) descibed that within the combinatorial scheduling community, there has been an increasing interest in modelling and solving scheduling problems in dynamic environments.

Laha and Gupta (2018) proposed an improved cuckoo search algorithm (ICSA) to minimize makes pan for the identical parallel-machine scheduling problem. Hjertqvist and Östman (2017) examined how equally sized batches affect the length of the production plan, and what batch size is optimal to achieve efficient production planning. The examination was conducted with respect to lean principles and a mathematical model was built to simulate the use of different batch sizes. Beck and Glock (2016) studied the Economic Lot Scheduling Problem (ELSP) for the single-machine-multi-product case. It is assumed that a lot may be split up into batches, which are then shipped individually to the consuming stage. Arroyo et al. (2017) addressed the problem of scheduling a set of n jobs with arbitrary job sizes and non-zero ready times on a set of m unrelated parallel batch machines with different capacities so as to minimize the makespan. Ge et al. (1999) developed an iterative dynamic optimization methodology for on-line optimization of batch processes in the presence of plant-model mismatch and measurable error. In his proposed method, the plant-model mismatch is effectively eliminated by using information from previous batches to modify the trajectories that are applied to the subsequent ones. Hulett et al. (2017)suggested a scheduling model with a set of Batch Processing Machines (BPMs) used to test printed circuit boards in an electronics manufacturing facility. The facility is used to assemble and test printed circuit boards of different sizes.

Modrak and Pandian (2010; 2011) proposed a flow shop scheduling algorithm to minimize completion time for n-jobs m-machines problem. Koole and Righter (2002) considered a batch scheduling problem in which the processing time of a batch of jobs equals the maximum of the processing times of all jobs in the batch. Sarker and Newton (2000) considered two unconstrained non-convex optimization programs which represent joint raw material-production batch sizing problemsin a real world situation. Basir et al. (2018) suggested an integrated production and distribution scheduling on a two-stage assembly flow-shop setting with a batch delivery system. Semanco and Modrak (2012) offered constructive heuristic approach for the solution of the permutation flow-shop problem. The scheduling problems of flexible manufacturing cells were analyzed by Dima et al. (2011). Li et al. (2012) presented a paper to find an optimal batch sequence. The sequence is to minimize the maximal completion time and maximize the minimum value of desirability of the fuzzy precedence. Chiu et al. (2011) developed a mathematical modeling and algebraic approach to derive the optimal manufacturing batch size and number of shipment for a vendor-buyer integrated economic production quantity (EPQ) model with scrap. But it is very hard to find any approach that makes flexibility for scheduling in mass customized environment.

Problem Description

The assumption is that one supplier receiving different orders (jobs) with different quantity from one or more original equipment manufacturer (OEMs). Such problem is typical, e.g., in automotive sector, where there is a need for millions of small parts to be assembled during the production of Cars or Lorries. The Hungarian automotive sector can be characterized as somewhat one-sided: it consists of by few large international OEM’s like Audi, Mercedes-Benz, Opel, Suzuki, Raba (Szegedi et al., 2017). In this study, there are two major OEMs (A and B) and there exits five production locations of vehicles for each type as shown in Figure 1, where number of different parts demanded are communicated to the supplier periodically.

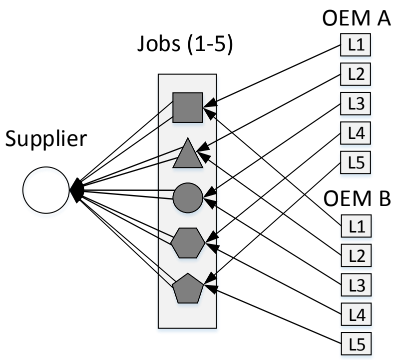

Figure 1. Jobs requirement to various locations of OEM - A and B

For instance, in each type of vehicle 50000 parts are required in sum of all production locations of OEM-A and B are as given in the Table 1.

Table 1. Quantity of the parts required by OEM - A and B

Location	Quantity required for OEM -A	Quantity required for OEM -B
L1	11500	10000
L2	9500	9000
L3	10000	10500
L4	9500	10000
L5	9000	11000
Total	50000	50000

There are 5 different models of parts to be processed for these two types of OEMs (A and B) and delivered in batches to various locations as mentioned in Figure 1. The processing time of each model to locations of OEM - A and locations of OEM - B is given in Table 2.

Table 2. The processing time (secs) of five models for OEM – A and B

	J1A	J1B	J2A	J2B	J3A	J3B	J4A	J4B	J5A	J5B
M1	8	8	6	6	8	8	6	6	7	7
M2	6	6	1	1	7	7	5	5	5	5
M3	8	8	8	8	7	7	7	7	2	2
M4	7	7	8	8	7	7	9	9	4	4
M5	9	9	5	5	9	9	6	6	5	5
M6	4	4	6	6	5	5	4	4	6	6
M7	5	5	8	8	4	4	7	7	7	7
M8	6	6	8	8	6	6	5	5	5	5
M9	8	8	4	4	6	6	7	7	5	5
M10	5	5	6	6	8	8	7	7	5	5

The Methodology (FLexible MAss CUStomization)

The following heuristics procedure for flexible mass customization has developed based on the study given by Modrak et al. (2018) where the procedure is implemented for municipal services.

Heuristics – FLAMACUS

Step-1: Get the job orders (in numbers) of all jobs (J1A, J1B, J2A, J2B …) from customers.
Step-2: Categorize (based on processing requirements) the job orders for production flow as per the available resources.
Step-3: Calculate make span for full batch size (q_n) of all jobs (whole lot).
Step-4: If the customer accepts the due date based on make span calculated in step – 3, retain the batch size. Go to step – 6, or else go to step – 5.
Step-5: Using the proprietary software, make the batch size for all jobs into next (q_{n-1}, q_{n-2} … q_2) and calculate the make span. Go to step-4.
Step-6: Reflect the results using Gantt Charts. Program Ends.

Illustrative Example

Assumptions:

- There are five different jobs considered for easy illustration purpose.
- The total customers 'orders given in table 1 are 50000 numbers for each OEM A and B.
- In the Table 2, the processing time for Jobs (1, 2, 3, 4, and 5) for OEM – A and B parts is given.
- The processing times are same for same job in both OEM – A and B.
- The supplier works for 24 hours a day.

The make span for the given batch size is calculated for all 5 jobs and total quantity of 50000 numbers for OEM A and 50000 numbers for OEM B. Then the Gantt chart is drawn as mentioned in Figure 2 and 3. In these figures, each colour denotes a transport batch of jobs (as mentioned in Table 2). In Figure 2, there are 500 numbers of each job in one batch and the total number of such batches is 200. In Figure 3, the batch size of each job is 5000 numbers and the total of 20 such batches are split. The numbers in X axis show the makes pan time in seconds. It is converted into days for calculation purpose. The total makes pan is 12 days. As per the steps given in methodology the batch sizes are reduced in steps; 10000, 5000, 4000, 2000, 1000 and 500. The makes pan becomes 16, 12, 11, 10.9 and 8.5 days respectively, when the batch sizes are reduced as shown in Figure 2 and 3.

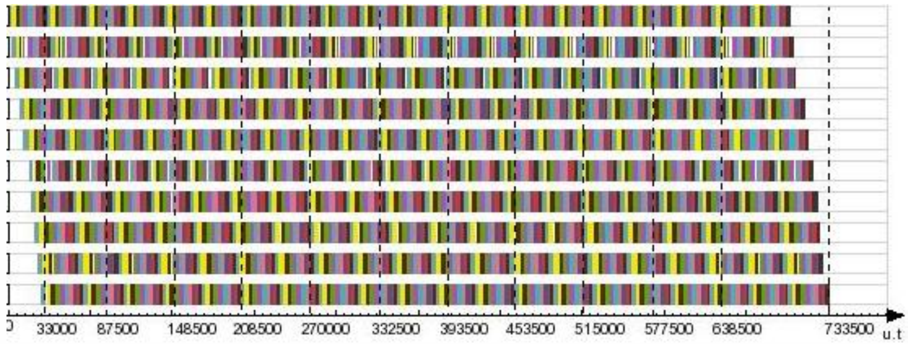

Figure 2. Gantt chart for Q=100000, batch size 500 Make Span – 8.5 days

In order to analyze, relations between Batch size and Make span is given in the graph as provided in Figure 4, when the batch size is 5000 and this batch is produced in 20 batches for 10 locations, the make span is 12 days. When the batch size is 500 and produced in 200 batches for 10 locations, the make span becomes only 8.5 days.

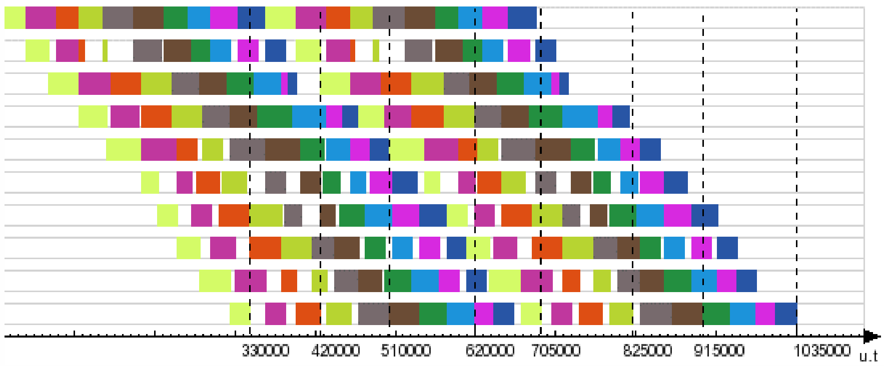

Figure 3. Gantt chart for Q=100000, batch size 5000 Make Span – 12days

From the graph shown in Figure 4, it is understood that the batch size of 1000 is optimal and it must be produced in 100 transport batches for 10 locations as for as the specific case considered in this example. The Table 3 shows the flow time of batches 5000x2x10 locations and 500x20x10 locations. The difference between the flow times is 3.5 days.

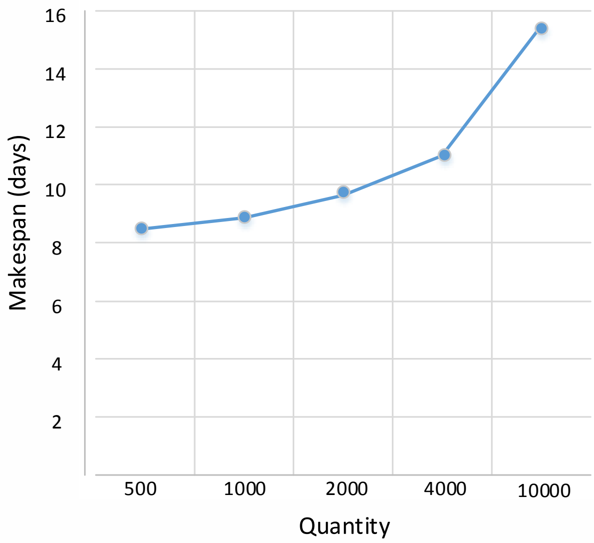

Figure 4. Batch size (X - axis in numbers) and Make Span (Y axis - in days

Results and Discussion

In the past, the researchers in their work, proposed suitable algorithms and various methods for calculating out batch size, optimal lead time, and makespan, for scheduling in flow shop or job shop specifically. In some extent, few researches have been found that considered the assembly line balancing and few studies are found in the field of optimization of production supporting processes (Łęgowik-

Świącik, 2015). These approaches failed to consider the mass production in mass customized environment (Man et al., 2011).

Table 3. Flow time of Jobs (1-5) for batch size 5000 and 500

	Flow time		Flow time		
Job	First batch of (5000x2) Days	Last batch of (5000x2) Days	First batch of (500x2)Days	Last batch of (500x2)Days	Diff
J1	4.0	9.0	0.47	8.1	0.9
J2	6.0	10.0	0.55	8.2	1.8
J3	7.0	11.0	0.68	8.4	2.6
J4	8.0	11.4	0.76	8.4	3.0
J5	8.0	12.0	0.81	8.5	3.5
	Total	12.0	Total	8.5	3.5

In this study, mass production with mass customized approach has been carried out based on the day to day changing in demand based on the market conditions. The results are shown in Figures (2-4). It is inferred from these figures that the customers have the flexibility of choosing their time span of delivery of products at different locations and it also depends on the batch size of the total orders placed. In this example problem, the total days are 12 when the batch size is 5000 numbers in 20 batches for 10 jobs (5 jobs into 10 locations). When the batch size is reduced to 500 numbers in 200 batches, the makespan become 8.5 days. Even though there are similar studies hardly found in the literature, to compare with few studies found in literature, it is considered in Modrak et al. (2018), the due dates are fixed earlier before starting the manufacturing and the corresponding batch size is drawn to satisfy the customer and so there is no flexibility in choosing duedates whereas, in our study the batch size and the corresponding due dates are made flexible to the customers (OEMs in this paper) so that the orders can be made based on the market demand of the final products.

– By this model we can set up due date and corresponding batch size for the Original Equipment Manufacturers.
– It is appropriate to have 5 jobs divided into 10 jobs so that the flow of production and delivery become easier with due date as per customer's satisfaction.

In general, the decision makers can vary the batch size and thereby making changes in the makespan to meet the required due dates based on demand in the market for different models.

Conclusions

In this study, the problem of mass customization with mass production was dealt with considering batch type production industries. Usually management makes decision on due dates for the products to be delivered to the customer. In the present study the customer is offered flexibility in choosing their delivery dates.

In the competitive environment, retaining customers become more challenging in nature. The customers are ready to spend more cost to save their time. Flexibility is one of the fruitful thoughts of the day which will help in getting more customers and also to retain old customers. Such concepts can be useful where more customers orders with varying in demand. Based on the flexible scheduling for mass customization problem studied in this paper by considering batch type original equipment manufacturing industry the following recommendations are made:

- The study can be useful to the management for immediate decision making,
- The customers are offered flexible scheduling and options to choose their delivery dates,
- Waiting time and processing time will be optimized,
- The skilled managers are required to find out flexibility for each customer separately,
- The labourers should be educated when there is every change in schedule to accustom based on the demand in the market,
- The methodology proposed is useful only there are huge orders at a single time,
- The idea can be extended with few more real time factors like, transport time, setup time, inventory cost, penalty cost to make the model more realistic for industrial application.

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ZARZĄDZANIE MASOWO SPERSONALIZOWANYMI ZAMÓWIENIAMI PRZY WYKORZYSTANIU ELASTYCZNYCH HARMONOGRAMÓW W CELU ZMNIEJSZENIA CZASU DOSTAWY

Streszczenie: Celem masowej personalizacji jest sprawienie, aby produkty i / lub usługi satysfakcjonowały indywidualnego klienta, który dokonuje zamówienia zgodnego z konkretnym projektem odpowiadającego jego potrzebom. W rzeczywistej sytuacji nie jest łatwo znaleźć indywidualny projekt i zadowolić każdego klienta osobno; istnieje potrzeba przystosowania takiego środowiska do zaspokojenia popytu na rynku. W takiej sytuacji decydenci muszą upewnić się, że działają elastycznie przy przyjmowaniu zamówień i wysyłaniu ich do klientów. Taka koncepcja rozwinięta została w niniejszej pracy badawczej. Głównym celem badania jest zaproponowanie procedury; elastyczną masową personalizację (FLMACUS) do tworzenia elastycznych harmonogramów spełniających wymagania klientów. Do opracowania procedury wykorzystano prostą heurystykę, natomiast do dostosowania zadań do spełnienia określonych terminów posłużyły wykresy Gantta. W artykule do celów badawczych wzięto pod uwagę Producentów Oryginalnego Sprzętu (OEM). W kolejnej części artykułu przedstawiono wyniki z wykresów Gantta w różnych kategoriach. Tego typu wykresy Gantta prawie nie występują we wcześniejszych badaniach, a wyniki pokazują, że ta procedura (FLMACUS) ma charakter obiecujący, aby sprostać wymaganiom klientów i terminom w masowo dostosowywanym środowisku.
Słowa kluczowe: masowa personalizacja, planowanie, wielkość partii

使用灵活的时间表管理大规模定制订单以最大限度地减少交付时间

摘要:大规模定制的目标是使产品和/或服务满足个别客户，他们根据需要为特定设计下订单。在实际情况下，满足个性化设计并满足每个客户并不容易。分别;需要习惯这样的环境来满足市场需求。在这种情况下，决策者应确保他们在接受订单时遵循灵活性并将其发送给客户。在这项研究工作中正在开发一个这样的想法。这项研究工作的主要目的是提供程序;灵活的大规模定制(FLMACUS)，以灵活的时间表，满足客户的要求。使用简单的启发式方法来开发程序，甘特图用于容纳满足特定截止日期的工作。在此纸张类型中，原始设备制造商(OEM)被认为是我们的研究目的。描绘了各种类别的甘特图的结果。在早期的研究中很难找到这类甘特图，结果表明，这种程序(FLMACUS)本质上很有前途，可以满足客户的需求和大规模定制环境中的截止日期。
关键词:大规模定制，调度，批量大小。