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## A framework for developing lot-sizing and scheduling model for multiproduct

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# A framework for developing lot-sizing and scheduling model for multiproduct

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**Abstract.** This paper considers the issue of lot-sizing and scheduling for multi-product production facilities using flexible flow lines. Flexible flow lines are also called flow lines with parallel machines at several or all stages of production with various products. The problem encountered in the company produce machine sparepart is a scheduling that is not optimal such as work rules that are not systematic causing a long of manufacturing time, but it also does not systematically result in scheduling a plan that is not optimal lot-sizing. In solving the problem, this paper proposes adjustments to scheduling planning and lot-sizing to improve the company performance. The objective of this study is to minimize processing time and production cost so as to satisfy customers. The expectation of the conceptual framework of the lot-sizing model and scheduling model is to be able to optimize lot-sizing and scheduling to achieve multi-objective goals of production time and production cost as a result of decisions related to many machine and lot size.

## 1. Introduction

The company's production plan is an important step before the production process is executed. The main concern in planning is the limitations of workers and constraints in shopfloor, especially the availability and capability of the machine as well as the time and cost of production. Therefore, production planning is needed. One of the production planning is determining the optimum lot sizes to be produced which can reduce production costs.

A common problem that occurs with regard to determining production lots is the imbalance in production costs between (but not limited to) inventory costs and holding costs that affect the company's performance. This will become even more complex when determining the quantity not only for one product but also for many products. Therefore, production costs also become more complex to reduce. To solve this problem, the determination of the production lots of each product must be optimized and considered together to reduce production costs.

In addition to the problem of determining lot-sizing, scheduling is an issue considered in this study. Scheduling is defined as the process set a series of tasks to resources from time to time [1]. Effective scheduling plays a very important role in today's competitive manufacturing world. Performance criteria such as machine use, production time, due date, customer satisfaction, and product quality depend on how efficiently the work is scheduled in the system. Especially when there are many types

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of products in production, scheduling problem will become more complex. Therefore, good scheduling is needed. This means that multi-product scheduling needs to be optimized by sorting jobs according to the character of each different job and machine.

This problem will be more complex when combining lot-sizing and scheduling because both will provide solutions and achieve objectives simultaneously. The solution to this problem is to minimize setup cost and inventory costs by optimizing production lot-sizing decisions while minimizing production process time by optimizing job sequences that are compatible with job and machine characteristics. This paper aims to build a framework that combines two complex problems as a solution to reduce inventory costs, set-up costs, and overall production time.

## 2. Literature Review

The issue of lot-sizing and scheduling has been studied since the advent of mass production and the concept of corporate philosophy. In general, papers have been published to solve lot-sizing problems using a heuristic or metaheuristic approach in recent years [2, 3].

Lot-sizing and scheduling can be divided into three sub-problems. The first problem is Lot-sizing Problem (LSP), which could be the focus when there is no arrangement between the various products or arrangement is not dependent sequentially. In this case, the main objective is to minimize inventory costs and set-up costs while other goals can maximize the overall throughput of the production line.

The second problem is a scheduling problem when the aim is to determine the allocation of work and sequence of work in each machine in a multi-machine environment. The scheduling problem can be divided into two main problems i.e. flow shop scheduling and job shop scheduling. In the flow shop scheduling problem, a set of machines is arranged in series and each job is processed on several machines in the sequence of the machines that have been determined [4]. While in the job shop scheduling problem, a job can be processed through different machines in any sequences [5].

The third problem is solving lot-sizing and scheduling problems simultaneously. It is common in the literature to solve the problem of lot-sizing and scheduling simultaneously while considering the timing or costings. The main goal in this case depends on the problem. The general objective besides minimizing inventory costs and processing time is to maximize throughput by optimizing setup time. This study focuses mainly on related work using genetic algorithms (GA) to solve various types of lot-sizes and scheduling problems.

### 2.1. Lot-sizing Problem

Xie and Dong [6] introduced a genetic algorithm (GA) to solve General Capacitated Lot-sizing Problems (GCLSP). They introduce the representation of solutions that encode the settings for each product as binary variables, while the other decision variables come from binary variables through coding and decoding procedures. The setup time in this case is an independent sequence while the setup fee depends on the product.

Gonzalez-Ramirez et al. [7] proposed a heuristic procedure to solve the Capacitated Lot-sizing Problem (CLSP) with the aim of maximizing profits by minimizing total costs, such as holding costs, production costs, and setup costs when cost management is set for each period in which production takes place. Apart from the fixed costs, the problem is still NP-hard. The complexity of the problem increases in the case of multi-products.

Toledo et al [8] state that in addition to the lot-size for each product, the algorithm determines whether certain types of products are produced during the specified period or not, without suggesting any sequences for an independent setting time sequence. On the other hand, the setup time depends on the product and cannot be ignored so that it is included in different limits to ensure the feasibility of all solutions.

### 2.2. Scheduling Problem

Scheduling problems are often associated with multi-machine problems. The purpose of scheduling problem solving is to find the best machine allocation for different tasks or jobs and find the optimal sequence to process the work on each machine [9].

Scheduling problems can be divided into two main categories: identical machines and non-identical machines. Chaudhry and Drake [9] introduced a genetic algorithm to minimize the total delay in identical multi-machine problems. Identical parallel machines mean that the setup time and processing time do not depend on the machine. In addition, Chaudhry and Drake [10] assume the set-up time does not depend on the sequence and machine capacity. Machine capacity can be determined by assigning a number of different workers to different machines during the production plan. The algorithm is used with the representation of chromosomes in the form of permutation vectors where this vector includes a list of jobs to be performed, the number of workers on each machine (machine capacity) and which machines will do each job. They conclude the effectiveness of using Genetic Algorithms to solve such problems.

Balin [5] proposed a genetic algorithm to solve non-identical parallel machine problems. He proposed chromosome representation in the form of a matrix in which each row represents a machine, each column represents the type of product and each cell in these chromosomes is 0 or 1, which indicates whether a product is manufactured on a specific machine or not. Each column has only one non-zero cell, and all other cells are zero. This means that each product can only be produced on one machine while each line represents a proper schedule for each machine. Because of this coding method, Balin [5] designed a new crossover operator that works on two lines of the same chromosome (one individual) and it works by moving non-zero cells from one row to another, which means moving jobs from one machine to another. This crossover operator works based on processing time for each machine to get a new individual with a better feasible schedule. He concluded that genetic algorithms are suitable for solving parallel machine scheduling problems that are not identical and promising results.

### *2.3. Lot-sizing and Scheduling Problem*

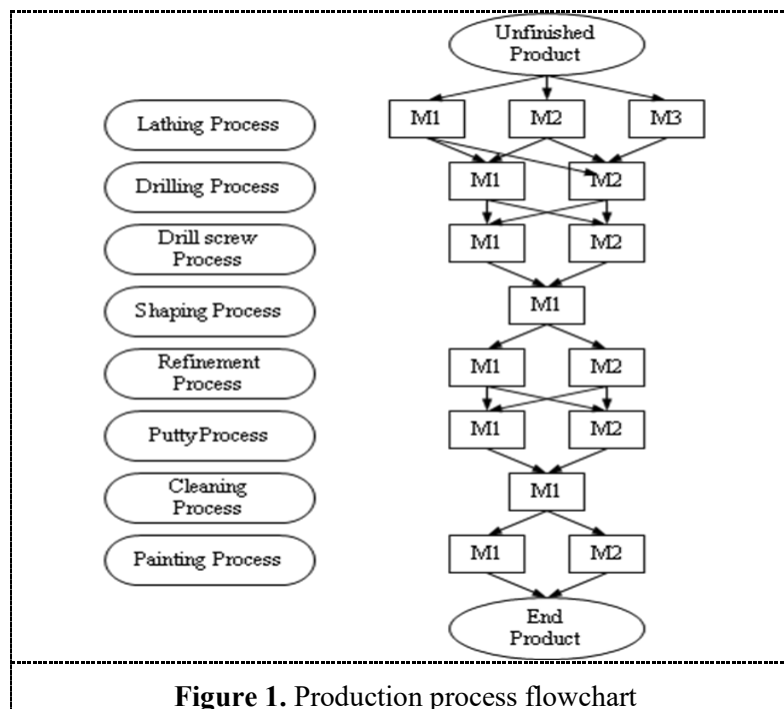
In many real cases, set-up depends on the sequence and has a significant effect on total costs and time. Therefore, lot-sizing and scheduling issues need to be studied simultaneously to find the best product sequence and lot-size for each product. Many algorithms have been used and many models have been proposed with different characteristics and assumptions.

Mohammadi et al.[11], introduced two rolling horizon approaches to solve a large size capacitated lot-sizing problem with sequence dependent setups, sequence dependency rises the importance of solving the lot-sizing problem and scheduling problem simultaneously. The algorithm works by choosing a product and setup the machine for it, and then it starts adding other products one by one. The sequence resulting from the addition of this product may be tried to all positions. For each position, the setup costs are calculated so that the position that produces the lowest total setup cost selected and the algorithm moves to the next product. This process is repeated for all periods independently. That means that the decision variable from one period does not affect the other periods. Mohammadi et al. [12] proposed a Genetic algorithm to solve the same problem with the representation of solutions in the form of a matrix. This matrix has the decision variables needed to decide which products will be produced during each period and the sequence of products in that period.

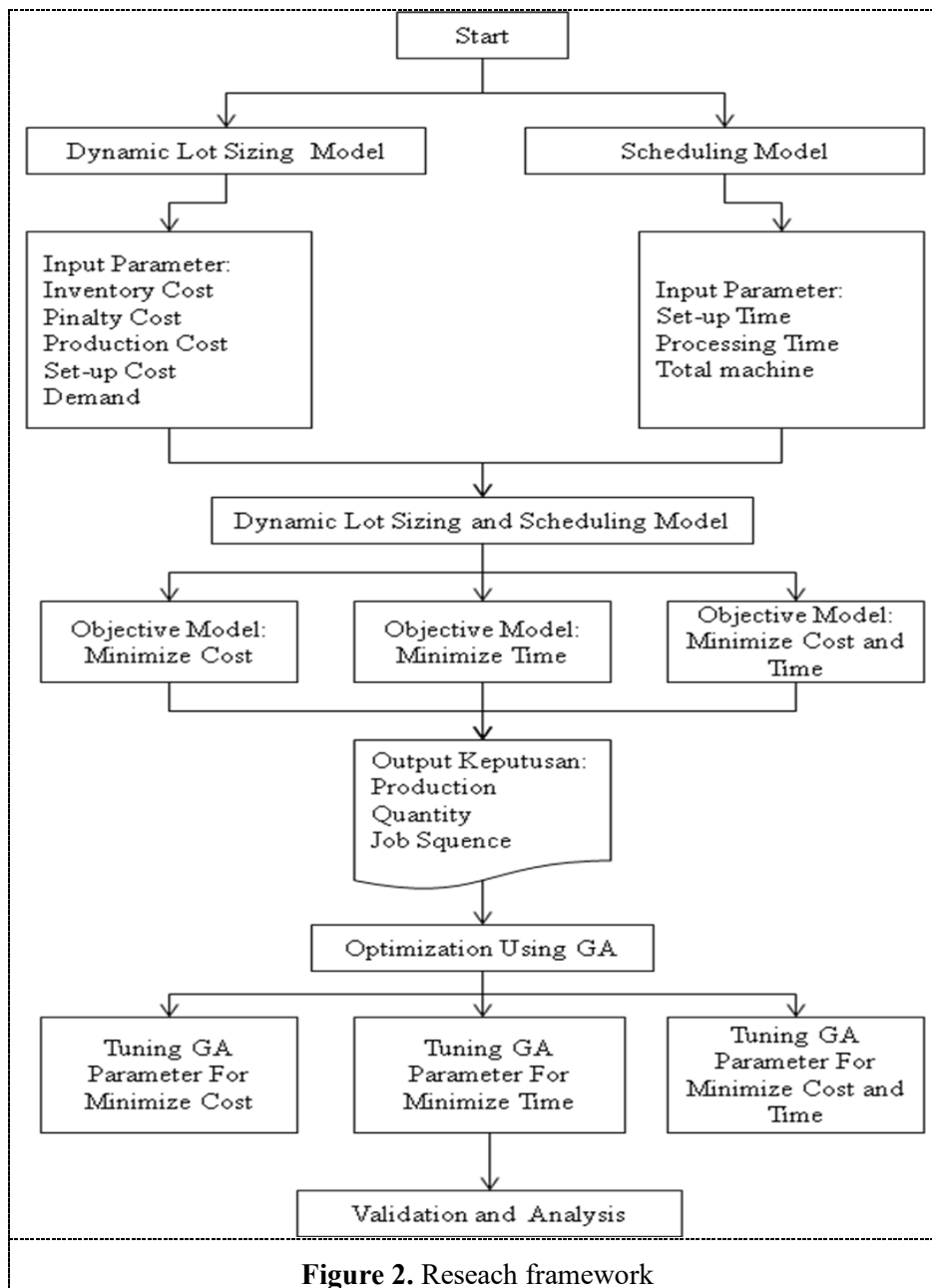
Mohammadi and Ghomi [13] solved the same capacitated single machine multi level lot-sizing problem by combining genetic algorithm (GA) with rolling horizon approach, they designed a genetic algorithm (GA) to determine the decision variables for each period while freezing other periods based on the rolling horizon approach. Genetic Algorithms proposed by Mohammadi and Ghomi [13] have been used with the representation of chromosomes in the form of vectors which show the sequence of products for one period since the Genetic Algorithm is applied for each period separately. This algorithm was superior to the previous rolling horizon approaches of Mohammadi et. al. [11], especially for large size problems.

### 3. Framework Methodology

This study uses a case study in a cast iron-based spareparts company. The company is trying to maintain stability of the company considering production costs, production time and production targets so that customer satisfaction can be achieved. To achieve this goal, the company need to control the production process to meet the expected quality and quantity of products according to production targets. In accordance with this problem, the company has emphasized techniques for applying a method that is implemented into the company's system. The problems that the company is currently facing are difficulty in determining the amount of production that can result in product deficiency or excess, no accurate technique to estimate the amount of production and no technique to determine the job sequence on each machine. In this case, the determination of the amount of production will affect the performance of the company including the cost of production, the cost of purchasing materials, warehouses and production time.



Based on the company's data collection in interviews with employees, there are several types of products manufactured so it is necessary to adjust the production process according to customer demand. Figure 1. shows the flow of the production process from the initial stage to the final stage. Irregular production flow makes the production process requires a long time because it can not adjust the job sequence to each machine optimally. Therefore, companies need to prepare for the production process by optimizing the lot-sizing of production and optimizing job sequences accordingly so that good scheduling is needed to optimize production in this company.



In the diagram above, we can see the flow in making solutions to lot-sizing and scheduling problems. In this case, this study recommends some solutions that must be done by creating a conceptual model that is designed to help planners that are made to make decisions related to industrial resources. The model is a simple representation of the system or the real problem in the industry. Models can provide solutions to situations or complex problems. The methodology of the study consists of 4 phases which can be seen in Figure 3.:

		Type	ProductionStage	Objective
Phase I	Model Development	Lot sizing	All stage	Minimize cost
Phase II	Model Development	Scheduling	All stage	Minimize processing time
Phase III	Model Integration	Lot sizing and scheduling	All stage	Minimize cost and processing time
Phase IV	Validation	Lot sizing and scheduling	All stage	Minimize cost and processing time

Figure 3. Phase of method solving problem

### 3.1 Phase 1. Build a conceptual model of lot-sizing

This study uses a dynamic lot-sizing model scenario. This model is related to the production process of products to meet customer demand that is dynamic with different amounts at each period. For example, Figure 4. shows the five production design periods.

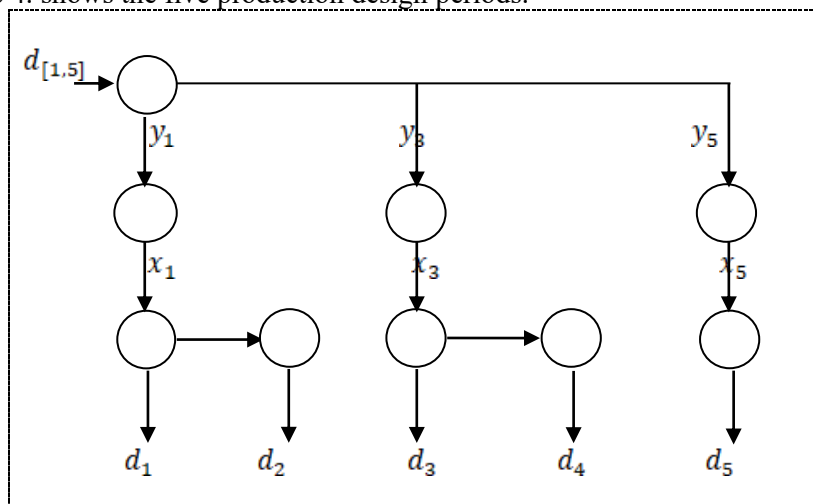


Figure 4. The network of production process with inventory

The company determines the period during which production will be carried out at a certain amount to meet demand. As shown in Figure 3, production is carried out at points  $y_1$ ,  $y_3$  and  $y_5$ . with a certain amount of  $x_1$ ,  $x_3$ , and  $x_5$  respectively by considering the inventory for each period. In this case, the production carried out by the company is subject to supply costs per supply in designing the production at points  $y_1$ ,  $y_3$  and  $y_5$ . In addition, the company also issued production costs per unit produced at points  $y_1$ ,  $y_3$  and  $y_5$ .

After going through the production process, the product is stored in a warehouse which is subject to inventory costs per unit. Warehouse capacity in the company's warehouse is limited. If there is excess product in the company's warehouse, the company will be charged with a holding cost penalty for each product. This is because companies have to do more maintenance or rent additional warehouses for excess products. Once the products are manufactured in accordance with the number of customer requests then the product is sent in each period.

In fact, there are transportation costs incurred by the customer for each shipment made. However, the reserved model does not consider transportation costs because the model built is only in the scope of the company which is examined as a form of simplification of the model.

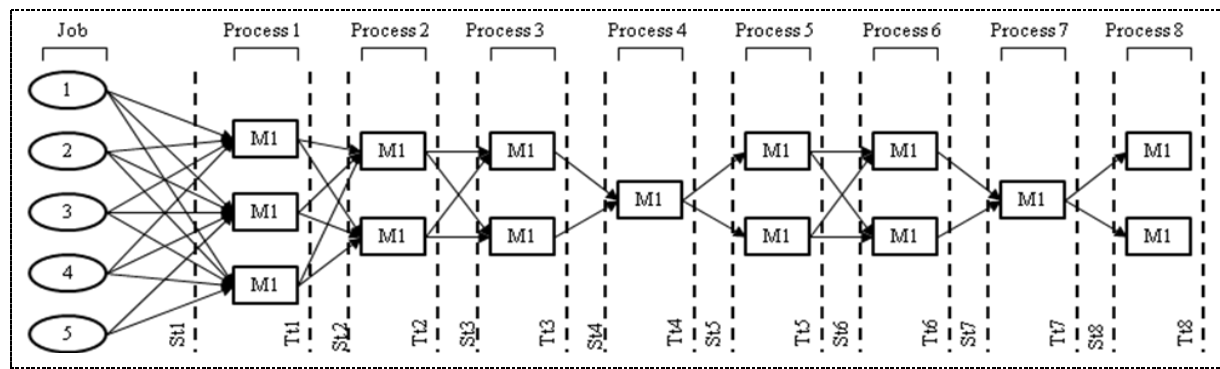
Based on this reason, the model is then developed using mathematical programming techniques which include setup costs, production costs, inventory costs, and penalty costs with consideration of dynamic demand. The aim of the model is to reduce the system cost by optimizing the quantity or lot production.

**3.2 Phase 2. Build a conceptual model of scheduling**

Based on Figure 5, the scheduling component consists of jobs, machines, setup time and processing time. Each product has a different processing time so that it becomes one of the factors that influence scheduling. This study examines several jobs that have different characteristics. The job represents the number of products manufactured in the case study of the machinery spare parts industry. Each product or job is then processed using a machine that has certain characteristics to turn a semi-finished product into a finished product. Based on Figure 1, each stage has a different process.

In addition, jobs assigned to each machine have different setup times and processing times. Therefore, all jobs that pass several machines considering setup time and processing time will produce total time. In this case, the scheduling problem is focused on the problem of the time needed to complete the job.

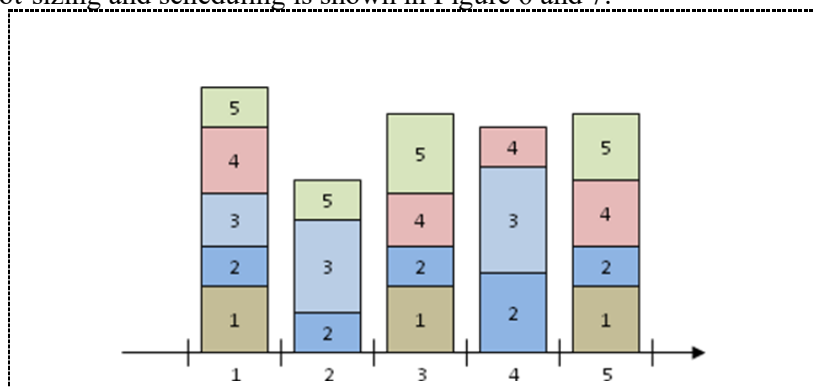
To complete the whole job by considering due date, a good scheduling is needed to avoid tardiness and earliness. Therefore, the purpose of the scheduling model is to reduce production process time by optimizing the production job sequence.



**Figure 5.** Schematic view of line production.

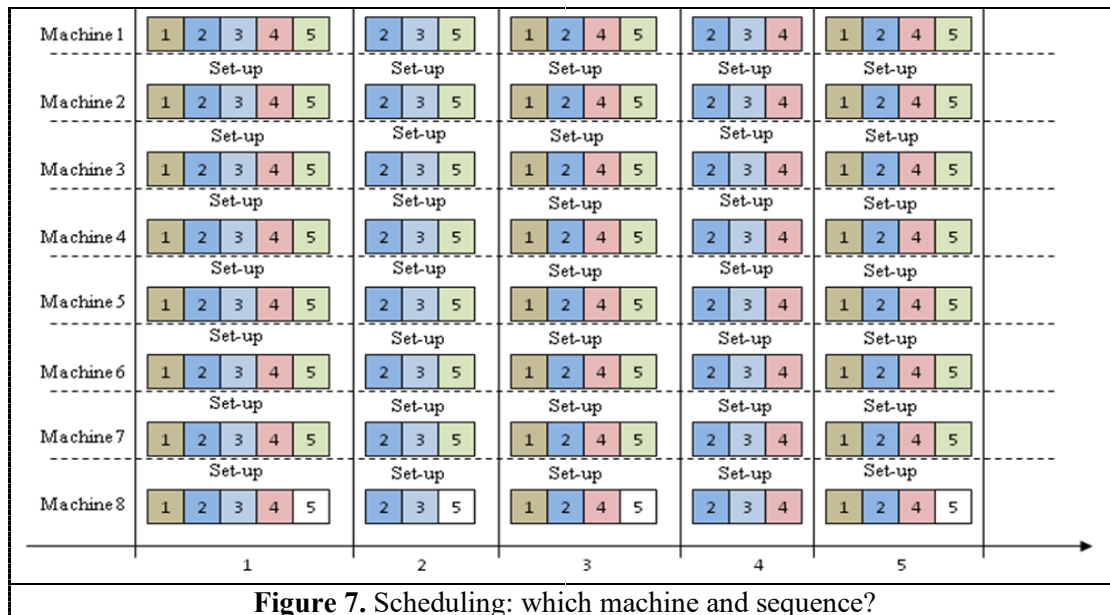
**3.3 Phase 3. Combining the two models of lot-sizing and scheduling**

As explained previously, lot-sizing explains some of the number of products that must be manufactured in each period while scheduling is related to job setting for production machines. The relationship of lot-sizing and scheduling is shown in Figure 6 and 7.



**Figure 6.** Lot-sizing: What quantities in which period?





Based on Figure 6 and 7, the combination of lot-sizing and scheduling is focused on five products i.e. 1, 2, 3, 4 and 5 which must be produced on eight machines in five periods. Lot-sizing is related to the number of products while scheduling considering machines and specific product sequences. The problem of the integration model between lot-sizing and scheduling considered is to reduce production costs and production time simultaneously. Therefore, the model reserved for this study has two important objectives. This can be achieved by optimizing production lots, especially for lot-sizing problems. Meanwhile, scheduling problems can be solved by optimizing work bookings. Both the optimization process must then be run simultaneously for 5 planning horizon that has been set.

### 3.4 Phase 4. Model validation

At each phase that has been described previously, this study proposes three models: a conceptual model of lot-sizing, the conceptual model of scheduling, and integration combination of lot-sizing model and scheduling model. The purpose of the first model is to reduce production costs while the purpose of the second model is to reduce production time and the purpose of the third model is to reduce production costs and production time simultaneously. These three models were developed based on the form of mathematical models coded in Microsoft excel, while optimization was done using the genetic algorithm (GA) method. Genetic algorithm (GA) is used to find production quantities and job sequences applied to 3 models. This means that although the 3 proposed models have different purposes, the optimization performed with GA is subject to lot-sizing and job sequence optimization.

To validate the three models, the performance of each model was compared. Furthermore, this raises the question of model validation:

- How capable genetic algorithm (GA) to optimize production lots and job sequences to reduce production costs.
- How does the decision affect lot-sizing and job sequence that reaches minimum production cost on production time?
- How capable genetic algorithm (GA) to optimize production lots and job sequences to reduce production time.
- How does the decision affect lot-sizing and job sequence that reaches minimum production time on production cost?

- How capable genetic algorithm (GA) to optimize production lots and job sequences to reduce production time and production cost simultaneously.
- How to analyze the validity of decisions by considering lot-sizing, scheduling, production time, and production costs every minute.

#### 4. Summary and Conclusions

Based on a case study on a spare parts company made from cast iron. This study has considered the conceptual development of lot-sizing and scheduling models to overcome the lotsizing and scheduling problems that occur in the company. The framework component consists of 4 phases where the first phase builds the concept of lot-sizing model, the second phase builds the conceptual scheduling model, the third phase combines the lot-sizing model with the scheduling model and the fourth phase validates the first three models based on the mathematical model form coded in Microsoft Excel , while the optimization is done by the genetic algorithm (GA) method. Genetic algorithm (GA) is used to find the production quantity and job sequences that are applied to three models. The aim of each model is to reduce production costs, production time, and production costs and production time simultaneously.

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