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Analysis of Effectiveness Lot Sizing Based on Design of Experiment

Analisis Efektivitas Penentuan Ukuran Lot Berdasarkan Rancangan Percobaan

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Abstract

Lot sizing techniques have been widely analyzed by experts, because ordering costs, storage costs, and lot sizes have a significant impact on the total cost of ordering. This study uses lot sizing techniques including Wagner-Whitin algorithm, Silver-Meal algorithm, Least Unit Cost, Least Total Cost, Part Period Balancing, Period Order Quantity, Groff algorithm, and Lot for Lot. The data used is taken from a chemical raw material procurement company, including ordering and storage costs. The initial analysis concluded that the Silver-Meal algorithm and the Groff algorithm have relative biases that are close to the Wagner-Whitin algorithm. The second analysis concluded that for the lot sizing technique, the calculated F value (84.3) was greater than the F table value (2.1), indicating a significant effect of the lot sizing technique on the relative bias percentage. Furthermore, the demand analysis shows that the calculated F value (80.0) is greater than the F table value (2.6), indicating a significant influence of the demand on the percentage relative bias.

Keywords: *Inventory, Lot Sizing Method, Design of Experient.*

Abstrak

Teknik lot sizing telah banyak dianalisis oleh para ahli, karena biaya pemesanan, biaya penyimpanan, dan ukuran lot memiliki dampak yang signifikan terhadap total biaya pemesanan. Penelitian ini menggunakan teknik lot sizing antara lain algoritma Wagner-Whitin, algoritma Silver-Meal, Least Unit Cost, Least Total Cost, Part Period Balancing, Period Order Quantity, algoritma Groff, dan Lot for Lot. Data yang digunakan diambil dari sebuah perusahaan pengadaan bahan baku kimia, termasuk biaya pemesanan dan penyimpanan. Analisis awal menyimpulkan bahwa algoritma Silver-Meal dan algoritma Groff memiliki bias relatif yang mendekati algoritma Wagner-Whitin. Analisis kedua menyimpulkan bahwa untuk teknik lot sizing, nilai F hitung (84,3) lebih besar dari nilai F tabel (2,1), yang mengindikasikan adanya pengaruh yang signifikan dari teknik lot sizing terhadap persentase bias relatif. Selanjutnya, analisis pola permintaan menunjukkan bahwa nilai F hitung (80,0) lebih besar dari nilai F tabel (2,6), yang mengindikasikan adanya pengaruh yang signifikan dari pola permintaan terhadap persentase bias relatif.

Kata Kunci: Inventory, Metode Lot Size, Penelitian Eksperimen.

1. Introduction

Throughout every activity of human life, it cannot be separated from the need for an item to fulfill the interests of life. In a company, it cannot be separated from the need for an item. However, it can be distinguished the type and amount of goods needed, so as not to cause an error and waste that will result in a loss that will be borne by the company. Currently, competition between companies is no longer limited locally, but includes regional and global areas. Every company is competing to continuously look for efforts and ways to be able to compete and have a competitive advantage in order to survive and develop. The competition includes price, quality and service issues. Prices are often determined by costs, and the costs themselves are determined by the results of the determination and production process of the

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company. One of the high cost components is the procurement of goods, both direct goods and indirect goods, this includes the pattern of goods management, which is more specifically the management of goods inventory, (Song, 2021); (Suherman et al., 2023).

The existence of management requirement planning (MRP) in a company determines the stability of a production or asset that will determine whether a company runs or not. For this reason, it is necessary to create and manage an inventory system so that it will generate maximum profit for the company. Maximum profit can be obtained by managing the business effectively and efficiently. In this case, the role of management as manager and controller of all company activities is needed. One of them is the determination system about the lot sizing method. In the production system is a very important area, so the aspects of lot sizing have been widely analyzed by experts where the ordering cost is very sensitive to the order quantity. In practice with very complex situations, standard lot sizing techniques cannot be directly used, so practitioners tend to develop the use of standard lot sizing methods. (Susanti, 2020; Putri & Rosydi, 2020; Haryani & Aldini, 2022).

Inventory system planning with discrete demand aims to be able to provide products at the right time and quantity, according to consumer needs at the lowest cost level. And it happens at certain time intervals or certain times throughout the planning horizon. Inventory system planning with discrete demand uses the basic logic of Time phased Order point (lot sizing) for planned order receipt which can minimize the total cost of Setup Cost and Holding Cost as a basis for determining replenishment orders in MRP, (Puspita et al., 2020; Najy, 2020; Rimawan et al., 2018). One of the techniques involved in MRP is lot sizing, which is concerned with balancing the set-up cost/order cost or storage cost associated with the calculated net requirement of the MRP planning process. (Badri et al., 2020; Budde et al., 2022; Florim et al., 2019).

The loting techniques used in this study include Groff's Algorithm, although it is less commonly used than techniques such as Silver and Meal. (Walujo & Koesdijati, 2022; Poolcharuansin et al., 2018), Least Unit Cost (Al-najjar, 2022; Florim et al., 2019), Least Total Cost (Mahdi et al., 2018; Vania & Yolina, 2021), Part Period Balancing (Odedairo & Ladokun, 2018; Prakaiwichien & Rungreunganun, 2018), Period Order Quantity (Abdullah et al., 2020; Yıldız & Yaman, 2018), and Lot-for-Lot (Huda & Hartati, 2021; Kurniawan & Raphaeli, 2018).

There have been many studies on lot sizing techniques, with various techniques used in the research, some are directly applied to a company and some are in a research case. Therefore, the problem that will be discussed in this study is to determine the effectiveness of lot sizing techniques using raw material demand data from chemical companies. The problem formulation in this research is as follows, what is the effectiveness of the existing condition of the lot sizing method with the response variable average relative bias percentage.

2. Method

2.1 Inventory

The term "inventory" describes products or commodities that are kept for a specified use, including manufacturing or assembly procedures, equipment spare parts, or retail sales. Three types of inventory are distinguished by their functions: lot-size inventory, which is kept in greater quantities than are required at any given time;

fluctuation stock, which is kept to meet erratic demand; and anticipation stock, which is kept to meet predictable demand fluctuations, like seasonal demand. Raw materials, parts/components, supplies, work-in-progress, and finished goods are the five categories into which inventories can be categorized based on their physical form. Inventory-related expenses can be divided into four categories. (Gurtu, 2021; Onanaye & Oyebode, 2019); (Hamadneh et al., 2024).

Inventory refers to materials or goods that are stored for a specific purpose, such as production or assembly processes, spare parts for equipment, or for sale. Based on their function, inventories are categorized into three types: lot-size inventory, which is held in larger quantities than needed at the time; fluctuation stock, which is held to address unpredictable demand; and anticipation stock, which is held to address predictable fluctuations in demand, such as seasonal demand. In terms of their physical form, inventories can be classified into five types: raw materials, parts/components, supplies, work in process, and finished goods. Costs associated with inventory can be categorized into four types (Gurtu, 2021; Onanaye & Oyebode, 2019): 1). Storage costs, which include capital costs, handling, storage, obsolescence, depreciation, and other expenses that directly change based on the amount of inventory; 2). Ordering or procurement costs, which include the administrative expenses related to buying from suppliers; 3). Production or setup costs, which occur when materials are made internally instead of being bought; and 4). Shortage costs, which occur when inventory levels are not high enough to satisfy demand.

2.2 Lotting

The process of figuring out how many item components are needed to fulfill production process specifications is known as lot sizing. To meet demand in a production system, lot sizing employs a variety of strategies, such as:

1. Wagner-Within algorithm: a dynamic programming approach that uses simple algorithms in its calculations. This technique considers all possible combinations to take the optimal lot size (Czajkowski et al., 2019; Hanafizadeh et al., 2019);
2. Groff algorithm: developed by Groff (1979), based on determining the maximum lot size. It is a heuristic algorithm that selects the lot size covering the demand for a certain period, achieving the minimum total cost (Baciarello et al., 2013);
3. Silver-Meal algorithm: developed by Edward Silver and Harlan Meal based on the period cost. It is a heuristic algorithm that selects the lot size covering the demand for a certain period, achieving the minimum total cost (Walujo & Koesdijati, 2022; Poolcharuansin et al., 2018);
4. Part Period Balancing: similar to the least total cost technique, this method also evaluates the lot sizes by considering future or past periods. This technique utilizes all available information in the demand schedule and uses lot sizing to determine the order quantity based on a balance between ordering and holding costs to meet the demand. This method selects the number of periods required to meet additional orders based on accumulated holding and ordering costs (Odedairo & Ladokun, 2018; Prakaiwichien & Rungreunganun, 2018);
5. Period Order Quantity: a calculation that focuses on demand at a fixed period based on modifications to the EOQ. This technique adjusts for the real situation where net requirements may not be uniform and continuous (Abdullah et al., 2020; Yıldız & Yaman, 2018);
6. Least Unit Cost: a method that uses the convexity property of per-unit costs (ordering and holding costs) against the order quantity to determine the optimal

lot size. The optimal order quantity occurs at the lot size where the per-unit cost is the lowest (Al-najjar, 2022; Florim et al., 2019);

7. Least Total Cost: a method of inventory management that seeks to balance holding and ordering costs by determining the ideal lot size (order quantity). The goal is to reduce the total cost of inventory by striking a balance between the costs of keeping items and those of placing orders (Al-najjar, 2022; Florim et al., 2019);
8. Lot-for-Lot Method: where the order quantity is equal to the demand for each period, meaning the planned order quantity is always the same as the total net requirements per period. This heuristic method is the simplest lot sizing method, minimizing inventory investment while allowing lead time reduction and manufacturing process flexibility. This is consistent with the goal of lot sizing in just-in-time production, where the setup cost is zero (Huda & Hartati, 2021; Kurniawan & Raphaeli, 2018).

2.3 Design and Analysis of Experiments

Three terms are used in this context to refer to design: Designing entails organizing things beforehand and deciding what has to be done. Design: anything that has been planned, prepared, programmed, or designed. Designing: the process, specifics, or complexity of designing. In this context, "design" means "to design." Analysis is the process of making inferences from experimental data. An experiment can be defined as a deliberate inquiry to gather new information, confirm or refute prior experimental results, or as a series of trials or tests carried out by controlling several conditions to create quantifiable outcomes (the features being examined). Thus, designing experiments and discussing the statistical analysis that will be applied constitute experimental design and analysis, (Suherman et al., 2023); (Suherman et al., 2023); (Suherman et al., 2023); (Botha et al., 2021; Dangat et al., 2021); (Maier et al., 2019). Pattern of anova table as below:

Table 1. Analysis of Experimental Design

Variance Source	df	Sum of Squares	Root Mean Squares	F_0
Factor A	$a-1$	$JKA = \frac{\sum_{i=1}^{a} Y_{i..}^2}{bn} - \frac{T_{...}^2}{abn}$	$KTA = \frac{JKA}{(a-1)}$	$\frac{KTA}{KTE}$
Factor B	$b-1$	$JKB = \frac{\sum_{i=1}^{b} Y_{i..}^2}{an} - \frac{T_{...}^2}{abn}$	$KTB = \frac{JKB}{(b-1)}$	$\frac{KTB}{KTE}$
Error	$ab(n-1)$	$JKE = JKT - JKA - JKB$	$KTE = \frac{JKE}{ab(n-1)}$	$\frac{KTB}{KTE}$
Total	$abn-1$	$JKT = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k}^{n} Y_{ijk}^2 - \frac{Y^2}{abn}$		

2.4 Statistics Analysis

One of the statistical strategies used to evaluate hypotheses for k-correlated samples includes both parametric and non-parametric statistics. Parametric statistics, such as the Analysis of Variance (Anova). (Riza et al., 2021), are used when the data are interval or ratio in nature (Botha et al., 2021; Dangat et al., 2021). Anova can be used to compare k paired or unpaired samples. Two-way Anova is a sort of variance analysis used to assess the comparative means of k samples, each of which comprises of two or more categories, (Riza et al., 2021). The mean cell model may explain the response observations from a two-factor factorial experiment, with factor A having a levels and factor B having b levels, (Kritikos et al., 2019).

Here are to steps of reseach methodology as a table below:

Table 2. Research Methodology

Number	Description
1	Statement of Problems: to examine the effectiveness of lot sizing techniques and demand data on the response variable of relative percentage bias, we conducted an empirical study
2	Determining Factors: lotting technique method and demand data. Levels Factor: seven lotting techniques
3	The Determination of Response Variables: The response variable in this experiment is the relative percentage bias = $\sum_{i=1}^{N}(100(H_1 - OPT_1)/\,OPT_1)$
4	Experimental Design Selection: the total cost value of each data set is denoted as H_i, while the optimal solution value from the Wagner-Within algorithm is represented by OPT_1. The relative bias is computed as the discrepancy between the total cost of each lotting technique and the total cost yielded by the Wagner-Within algorithm. The effectiveness of the heuristic lotting technique is determined by whether the relative bias value is zero or not. Using a two-factor factorial design method to analyze the average relative bias percentage of lotting technique calculations (Riza et al., 2021).
5	Data Collection and Processing: – Data collection of 12 months' demand, inventory holding costs, and ordering costs. – Data processing of demand using the Wagner-Within algorithm. – Data processing of demand using various lot-sizing techniques (resulting in ordering and holding costs). – Calculation of these costs with a percentage relative bias for demand data. – The data demand calculation is performed using all lot sizing methods to obtain the average relative bias percentage. The next step is to calculate the difference in relative bias among all the data processing results.
6	Quantitative Approach: the decision based on the analysis of the experimental design using a factorial design will be made using anova method.
7	Conclusion: – The effectiveness of heuristic lot-sizing method compared to deterministic lot-sizing method is examined using a qualitative approach – The impact of demand on lot-sizing techniques is determined by analyzing the results of anova and the relative bias percentage as the response variable using a quantitative approach

3. Result and Discussion

Demand data for lot sizing approaches is calculated over a 12-month period. Groff's algorithm, Silver and Meal method, Least Unit Cost, Least Total Cost, Part Period Balancing, Period Order Quantity, and Lot for Lot are some of the data processing techniques employed. The Wagner Within method was used for comparisons, and the average total cost was Rp 4,360,000. Here is an example of how to compute the average relative bias percentage:

$$\%\,Relative\ Bias = \sum_{i=1}^{n}\left(\frac{100(5.142.000 - 4.360.000)}{4.360.000}\right) = 17{,}9$$

Table 3 provides a summary of the calculations. Furthermore, this study's conclusions were derived utilizing quantitative approaches, notably analysis of variance. A two-component factorial design was utilized to assess the average relative percentage bias in lotting procedure calculations.

3.1 Selection of the Optimal Lotting Technique

Based on the results of data processing, a summary of the average relative bias percentage is made that the lot for lot method provides the highest value which gives the greatest total cost incurred, while the lowest cost is generated from the calculation of the groff algorithm method as shown in the table below:

Table 3. Summary of the Average Relative Bias Percentage

No	Lotting Tech.	The Average of Percentage Relative Bias
1	Groff algorithm Silver	2
2	Meal	3
3	Least Unit Cost	10
4	Least Total Cost	9
5	Part Period Balancing	8
6	Period Order Quantity	8
7	Lot-for-Lot	18

Source: Data Processing, 2023

3.2 Analysis of Variance

After computing the percentage relative bias of the twenty sets of demand data, use the anova method to extract the total response variable from the data table. The goal of this study is to see if there is a relationship between factor B (demand data) and factor A (lotting approach). Hypothesis testing for factors A and B is as follows:

H_0: There is no effect of demand data on lotting technique with response variable relative bias percentage.

H_1: There is an influence of demand data on lotting techniques with the response variable percentage relative bias

The anova computation starts with calculating the correction factor, then the total sum of squares for components A and B, and finally the sum of squares for error. The results are as follows.

Table 4. Analysis of Variance

Variance Source	df	Number of Quadrant	Mean Quadrant	Value of F	F-tab (0,05)
A	6	7587,5	1264,6	84,3	2,1
B	3	3603,0	1201,0	80,0	2,6
Error	532	7984,6	15,0		
Total	541	19175,2			

Source: Data Processing, 2023

The table displays the results of hypothesis testing, which were:

a. The derived F value and F Table show that the F value above the critical threshold (84.3 > 2.1), indicating that the lotting process has a considerable effect on the percentage of relative bias.
b. The F value and F Table show that demand data has a considerable impact on percentage relative bias, above the crucial value (80.0 > 2.6). This shows that both variables have a considerable effect on the percentage relative bias.

4. Conclusion

The method's qualitative conclusion is shown in table 3, which shows that the silvermeal method obtained an average percentage of relative bias of 3, and the groff algorithm obtained an average percentage of relative bias of 2, which is closest to the calculation results of the Wagner within algorithm, which obtained a value of 0. This demonstrates that the heuristic lotting approach is still effective, as evidenced by the difference in relative bias value when compared to other lotting methods. Based on the findings of the analysis, the following conclusions can be inferred. It demonstrates that data processing using the anova approach leads to the conclusion that the first hypothesis, H_1, is accepted, implying that lotting processes have an effect on the percentage of relative bias. For the second hypothesis, H_1 is likewise accepted, indicating that demand data influences the proportion of relative bias.

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