Financial Assessment on Designing Inventory Policy by Considering Demand, Lead Time, and Defective Product Uncertainties: A Monte Carlo Simulation

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ABSTRACT
Inventory is one of the main components in supply chain. However, it is not easy to design inventory policy under uncertainties. The frequent occurrence of overstocks increases the company's financial expenditure. Otherwise, stockout decreases customer satisfaction and damage the company's image. This study aims to provide monte carlo model to design inventory policy with the aim of maximizing net income with a variety of uncertainties, one of the uncertainties is defective product because of the travel from suppliers. To handle the complexity and uncertainty of problem, a Monte Carlo simulation is used with spreadsheet-based representation. To test the reliability of the model, guitar company is used as relevant use case with uncertainty adhered 'the greater number of order quantity, the greater likely the defective guitar will be'. The verification & validation process, experimental design, and alternative selection are also done with statistical tests. Based on the simulation result, it is known that changing the reorder point to 80 and the order quantity to 90 gives the best result which can increase net income by 0.44% compared to the initial net income. In addition, the number of stockouts has decreased.

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INTRODUCTION

Guitar is one of the most popular musical instruments compared to other musical instruments [1]. This is because the price is not too expensive and also the convenience to carry everywhere. Generally acoustic guitars are often used to accompany singers, or even to play solo instrumentals. Now, almost everyone has a guitar, good for playing in the room, to make money by covering songs that are then uploaded to social media or to play in cafes. Therefore, the public interest in acoustic guitars continues to increase so that companies engaged in the production of acoustic guitars take advantage of this opportunity to achieve maximum profits.

ZackGuitar is one of the companies that sell acoustic guitar in Indonesia. ZackGuitar did not produce his own acoustic guitar, but was obtained from a ZikiZiba supplier from Taiwan. ZikiZiba has been trusted that the acoustic guitar supplied have excellent quality seen from the guitar model and the sound quality produced by the guitar. However, due to distant shipments, there are always uncertainty of number of defective guitars, the greater number of order quantity, the greater likely the defective guitar will be. Supplier has rules that the guitars sold cannot be returned with any reasons. Therefore, if the defective guitars received by ZackGuitar is high, it is worried that the company will lose. Defective guitars will be sold immediately to reduce the amount of loss at a cheaper price than the purchase price. To differ its guitar with others, ZackGuitar only gave a little variation by adding a batik pattern.

ZackGuitar is known as a seller of acoustic guitars that can be trusted by his customers, because guitars that are sold have good durability (not easily damaged). Therefore, guitars that are sold are quite expensive when compared to other guitars. Although the price is quite expensive, it still makes guitar lovers to buy it. Even guitars sold are often used up every day due to heavy demand. As a result of frequent stockouts, it has a negative impact on customer satisfaction [2]. Because it makes consumers often disappointed and gives a bad image to the company. This also had an impact on the profits obtained by the ZackGuitar company. The company feels that the profits obtained are not maximized, the company is worried that raising the selling price of each guitar will reduce the number of consumers because the prices pegged are quite expensive.

Currently, the company has alternatives to reduce stockouts that occur by increasing the number of orders from supplier and requiring inventory. Common problems in inventory management are stockout and overstock [3]. Therefore, it is necessary to evaluate which alternative can balance the stockout that occurs with overstock so that it is profitable for the company. However, the company is worried that if the number of guitars ordered from supplier are increased, the number of defective guitars will increase as well. While changing suppliers cannot be done because the customer already likes the quality of the guitar from the supplier.

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Based on the background that has been stated, the purpose of this study is to determine the effect of the alternatives given to the number of defective guitars that will be obtained which will affect the total profit obtained by the company. And also, to find out the alternatives given whether it can balance the number of stockouts with overstock that occurs. Therefore, in this study monte carlo simulation will be used by using Microsoft Excel which is spreadsheet-based representation. Spreadsheet is powerful tool and also quite convenient for simulation modeling, but it has four important disadvantages which are data structure limitation, hardness to implement complex algorithm, not fast enough for a lot of scenarios, and data storage limitation [4]. By implementing simulation, the losses of money and time from experiments given can be minimized [5].

Previous studies have conducted similar topics for designing inventory policy by using monte carlo simulation approach with different variables considered. Ramadan et al. (2020) [6] used monte carlo by considering probabilistic supply cost, Widyadana et al. (2017) [7] and Andriansyah et al. (2018) [8] considered intermittent demand as stochastic variable, Leepaitoon & Bunterngchit (2019) [9] applied monte carlo simulation for retail store by considering probabilistic lead time and demand, Belvárdi et al. (2012) [10] also used the same approach to simulate complex multi-echelon supply chains with their own interactive simulator. Compared with the previous researches, there is still no research in inventory problem that considers defective product as stochastic variable and analysis its effect on the inventory cost. However, practically that condition often happens where defective product occurs and cost the company. This research intends to include defective product as a stochastic variable from inventory perspective and learn its effect on inventory cost to determine a better policy for inventory improvement.

METHODS

Data Collection

There are several data taken in this study, namely reorder point, order quantity, warehouse capacity, and inventory cost which is obtained through interview with head section of inventory department who know the conditions of inventory and warehouse in ZackGuitar. In addition, researcher also uses some data from historical data like probabilistic demand, leadtime and defective product that company gets due to shipping from supplier

Simulation Modelling

In simulation modeling, monte carlo is used. Monte carlo is basically mathematical technique to predict the possible outcomes of an uncertain event based on sampling process of certain probability distribution. Monte Carlo is chosen because it does not need sophisticated software and does not explicitly contain time variable that makes simulation very expensive to run. It was built by using Microsoft Excel. It has been able to generate independent and uniform random numbers needed which both conditions are the main requirements of valid random numbers. Empirical probability distribution is made for uncertainty variables such as demand, lead time and defective product from historical data. In this stage, mathematical equations are made to model the relationship between variables using functions available in Microsoft Excel such as the Vlookup, IF, Random Number Generator and other relevant functions. The Monte Carlo model is then simulated for 1 month.

Model Validation

The model that has been constructed needs to be enhanced by using validation testing to see credibility of the model [4]. Validation can be done by comparing the output of the simulation result with the actual system [11]. In this study, non-parametric statistical tests are carried out by comparing the output of the simulation model with the actual system by using Chi-Square Test. The variable used to compare is the total profit for a month. Chi-Square test is used to test whether the frequency differences obtained from the two samples (model and real system) were significant differences or not [12]. The Chi Square test is very suitable to use when historical data is insufficient and a very dynamic system environment. The model will not be experimented if the model has not passed the validation stage.

Alternative Selection

Alternative selection is done by comparing the model of real system net profit with the scenarios that have been made. In the alternative selection steps, two tests will be carried out, namely One-way Analysis of Variance (Anova) and Bonferroni test. Anova is used to test the average difference between the initial models and other scenarios [13]. If Ho is accepted (there is no difference between the initial model and other scenarios), it means that the scenarios that have been made do not give significantly different results from the initial model. Whereas if Ho is rejected, then proceed with the Bonferroni test to see which of these scenarios are different from the original model and give the best result [14].

RESULTS AND DISCUSSIONS

Monte Carlo Simulation

Before the simulation is executed, it is necessary to make probability distributions as random number constraints using Lower Limit (LL) and Upper Limit (UL). Probability distributions are based on company historical data in the form of Demand showed in Table 1, Lead Time showed in Table 2 and Number of defective products arising from shipping goods of supplier for 60 guitars ordered in Table 3, Number of defective products for 80 guitars ordered showed in Table 4 and Number of defective products for 90 guitars ordered showed in Table 5.

Table 1. Demand probability distribution.

Demand (unit)	Frequency	Probability	Cumulative Probability	LL	UL
30	11	0,11	0,11	1	11
38	12	0,12	0,23	12	23
45	13	0,13	0,36	24	36
48	9	0,09	0,45	37	45
50	10	0,1	0,55	46	55
54	15	0,15	0,7	56	70
57	5	0,05	0,75	71	75
61	6	0,06	0,81	76	81
65	8	0,08	0,89	82	89
70	11	0,11	1	90	100
Total	100				

Table 2. Lead time probability distribution.

Lead Time (day)	Frequency	Probability	Cumulative Probability	LL	UL
1	25	0,23	0,23	1	23
2	37	0,35	0,58	24	58
3	45	0,42	1	59	100
Total	107				

Table 3. Number of defective products for 60 guitars ordered probability distribution.

Number of Defective Guitars (unit)	Frequency	Probability	Cumulative Probability	LL	UL
3	14	0,28	0,28	1	28
4	17	0,34	0,62	29	62
5	10	0,2	0,82	63	82
6	9	0,18	1	83	100
Total	50	1			

Table 4. Number of defective products for 80 guitars ordered probability distribution.

Number of Defective Guitars (unit)	Frequency	Probability	Cumulative Probability	LL	UL
3	9	0,18	0,18	1	18
4	14	0,28	0,46	19	46
5	17	0,34	0,8	47	80
6	10	0,2	1	81	100
Total	50	1			

Table 5. Number of defective products for 90 guitars ordered probability distribution.

Number of Defective Guitars (unit)	Frequency	Probability	Cumulative Probability	LL	UL
3	6	0,12	0,12	1	12
4	13	0,26	0,38	13	38
5	19	0,38	0,76	39	76
6	12	0,24	1	77	100
Total	50	1			

After the probability distribution has been made, Monte Carlo simulation modeling and its mathematical equations are made based on spreadsheet representation and relation. Then verification of the model is done by changing some variables into extreme value to see if all equations have been made correctly. The verified simulation model can be seen in Figure 1.

Validation

Chi-Square test is used to validate the model by comparing the total profit for a month in model with the actual system. By using 95% confidence level, it was found that $\chi 2$ calculated = 13.26 which is less than $\chi 2$ table = 19.67, so Ho is received. It means that there is no difference between the frequency of simulation data and the frequency of historical data. In other words, the simulation model can be used for experiment to find the best alternatives because the simulation model can respresent the real system.

Experimental Design

After the simulation was carried out using the MonteCarlo method, it was found that the average net profit of the 30 replications obtained by the ZackGuitar company was Rp269.655.333/month. Net profit is obtained from Equation 1.

Net profit = Gross Profit - Maintenance Cost – Batik Fee - Defect Losses

ZackGuitar wants to increase its net profit. Because the selling price of guitars is too expensive, so the selling price of the guitar / unit will not be raised. So that we try to change other variables to increase company revenue. In this study, there are 2 variables that can be changed, first is reorder point and second is order quantity.

Day	RN of Demand	RN of Lead Time	Total Demand (unit)	Lead Time (day)	Initial Inventory (unit)	Final Inventory (unit)	Sold (unit)	Overstock (unit)	Stockout (unit)	Gross Profit (IDR)	Maintenance cost (rupiah)	Stockout Losses (IDR)	Batik Fee (IDR)	RN of Defective Guitars	Defective Guitars (unit)
1	27	28	45	NOT BOOKING	100	55	45	55	0	22500000	1100000	0	4000000	84	0
2	6	64	30	NOT BOOKING	55	25	30	25	0	15000000	500000	0	0	38	0
3	55	84	50	3	25	0	25	0	25	12500000	0	5000000	0	84	0
4	76	58	61	2	0	0	0	0	61	0	0	12200000	0	55	0
5	78	77	61	1	0	0	0	0	61	0	0	12200000	0	52	0
6	4	7	30	ARRIVAL ORDER	60	30	30	30	0	15000000	600000	0	2400000	6	3
7	49	84	50	3	30	0	30	0	20	15000000	0	4000000	0	54	0
8	83	30	65	2	0	0	0	0	65	0	0	13000000	0	69	0
9	68	30	54	1	0	0	0	0	54	0	0	10800000	0	60	0
10	7	72	30	ARRIVAL ORDER	60	30	30	30	0	15000000	600000	0	2400000	32	4
11	86	15	65	1	30	0	30	0	35	15000000	0	7000000	0	59	0
12	76	28	61	ARRIVAL ORDER	60	0	60	0	1	30000000	0	200000	2400000	46	4
13	51	78	50	3	0	0	0	0	50	0	0	10000000	0	86	0
14	69	85	54	2	0	0	0	0	54	0	0	10800000	0	16	0
15	53	24	50	1	0	0	0	0	50	0	0	10000000	0	24	0
16	87	4	65	ARRIVAL ORDER	60	0	60	0	5	30000000	0	1000000	2400000	84	6
17	13	81	38	3	0	0	0	0	38	0	0	7600000	0	68	0
18	48	27	50	2	0	0	0	0	50	0	0	10000000	0	29	0
19	62	61	54	1	0	0	0	0	54	0	0	10800000	0	15	0
20	77	73	61	ARRIVAL ORDER	60	0	60	0	1	30000000	0	200000	2400000	83	6
21	81	24	61	1	0	0	0	0	61	0	0	12200000	0	83	0
22	18	42	38	ARRIVAL ORDER	60	22	38	22	0	19000000	440000	0	2400000	15	3
23	81	17	61	1	22	0	22	0	39	11000000	0	7800000	0	69	0
24	3	40	30	ARRIVAL ORDER	60	30	30	30	0	15000000	600000	0	2400000	3	3
25	3	33	30	2	30	0	30	0	0	15000000	0	0	0	50	0
26	3	81	30	1	0	0	0	0	30	0	0	6000000	0	66	0
27	22	39	38	ARRIVAL ORDER	60	22	38	22	0	19000000	440000	0	2400000	21	3
28	44	64	48	3	22	0	22	0	26	11000000	0	5200000	0	9	0
29	69	27	54	2	0	0	0	0	54	0	0	10800000	0	42	0
30	15	94	38	1	0	0	0	0	38	0	0	7600000	0	99	0
Total							**580**	**214**	**872**	**290000000**	**4280000**	**174400000**	**23200000**		**32**

Figure 1. Simulation model of real system.

In the first alternative (model of real system), the company requires a reorder point of 45 products and order quantity is 60 products. In the second alternative (scenario 1), the researcher will try to increase the reorder point to 60 and increase the order quantity to 80. In the third alternative (scenario 2), the researcher will try to increase the reorder point to 80 and increase order quantity to 90. It is done because the company still has sufficient warehouse capacity so that the alternatives provided can be applied by the company. The results of the experimental design carried out in 30 replications of the company's net profit for 1 month can be seen in Table 6.

Table 6. Experimental design result of company's net profit for 1 month.

Replication	Model of Real System	Scenario 1	Scenario 2
1	Rp262.260.000,00	Rp334.820.000,00	Rp370.020.000,00
2	Rp289.320.000,00	Rp371.080.000,00	Rp404.600.000,00
:	:	:	:
30	Rp288.920.000,00	Rp418.620.000,00	Rp461.540.000,00
Average	Rp269.655.333,00	Rp352.078.667,00	Rp388.959.333,00

Alternative Selection Results

Alternative selection is done by comparing between the model of real system net profit, scenario 1 and scenario 2. In the alternative selection steps, 2 tests will be carried out, namely Anova and Bonferroni. Following are the steps:

- Anova Test

Using a confidence interval: 95%, so the probability of error (α): 5% = 0.05. The Anova test results can be seen in Figure 2.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Model of Real System	30	7261960000	242065333,3	5,73046E+14		
Scenario 1	30	9368460000	312282000	8,62541E+14		
Scenario 2	30	10453810000	348460333,3	1,21781E+15		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1,75591E+17	2	8,77957E+16	99,26404012	3,53479E-23	3,101295757
Within Groups	7,69486E+16	87	8,84467E+14			
Total	2,5254E+17	89				

Figure 2. Result of anova test.

The value of F count = 99.26404012, while the value of F table = 3.101295757. Because the value of F count > F table, then Ho is rejected, so that there is a difference in average net profit generated by 3 different models both the model of real system, scenario 1, & scenario 2. Because there are differences, it is followed by the Bonferroni test to find out which model gives significantly different results and then take the best alternative.

- Bonferroni Test

Using a confidence interval: 95%, so the probability of error (α): 5% = 0.05. The Bonferroni test results can be seen in Fig. 3 by comparing each model so that there are 3 comparison results, namely between the model of real system with scenario 1, the model of real system with scenario 2, and scenario 1 with scenario 2.

	Model of Real System	Scenario 1
Mean	242065333,3	312282000
Variance	5,73046E+14	8,62541E+14
Observations	30	30
Pooled Variance	7,17793E+14	
Hypothesized Mean Differenc	0	
df	58	
t Stat	-10,15046882	
P(T<=t) one-tail	8,89743E-15	
t Critical one-tail	1,671552762	
P(T<=t) two-tail	1,77949E-14	
t Critical two-tail	2,001717484	
α/n = 0.016666667		

	Model of Real Systen	Scenario 2
Mean	242065333,3	347804828
Variance	5,73046E+14	1,248E+15
Observations	30	29
Pooled Variance	9,04581E+14	
Hypothesized Mean Difference	0	
df	57	
t Stat	-13,5004182	
P(T<=t) one-tail	1,05306E-19	
t Critical one-tail	1,672028888	
P(T<=t) two-tail	2,10612E-19	
t Critical two-tail	2,002465459	
α/n = 0.016666667		

	Scenario 1	Scenario 2
Mean	311509310,3	347804827,6
Variance	8,74795E+14	1,24796E+15
Observations	29	29
Pooled Variance	1,06138E+15	
Hypothesized Mean Differenc	0	
df	56	
t Stat	-4,242311249	
P(T<=t) one-tail	4,19047E-05	
t Critical one-tail	1,672522303	
P(T<=t) two-tail	8,38094E-05	
t Critical two-tail	2,003240719	
α/n = 0.016666667		

Figure 3. Result of bonferroni test.

Based on the testing criteria that if P (T <= t) two-tail <α / n then Ho is accepted. Looking at Figure 3 all comparisons show that P (T <= t) two-tail <α / n which means Ho is accepted or there is a difference in the average net profit a month between each alternative given. Then the next step is choosing alternatives that give the best results. Based on the experimental results of the second alternative (scenario 1), it was found that the net profit increased to Rp 352,078,667.00 which was originally Rp269,655,333.00. Whereas in the third alternative (scenario 2) it can be seen that the profit increases to Rp. 388,959,333.00 which is greater 0.44% than initial net profit. So that it can be said that the two alternatives provide better changes to the problem of net profit, where scenario 2 has the best profit because it has the highest value and greater 0.44% than initial net profit.

Based on the simulation results for 30 replications, it was found that the average stockout obtained in scenario 2 was lower than the initial model even though the overstock amount was greater. This is not a problem because the decrease in stockout has a larger presentation than the increase in overstock. And the company still has enough capacity to accommodate the amount of overstock. Because the main goal of the company is to increase its net income so that the increasing in overstock is still acceptable. Whereas if analyzed in terms of the number of defective guitars based on the alternatives given, the more the number of order quantity, the more the number of defective guitars. But the company does not need to worry, because the change in the number of guitars that are sold is more than the change in the number of defective guitars so that it will still increase revenue from the company itself.

CONCLUSIONS

Based on the discussion above, it can be concluded that alternative 3 is the best alternative that can be applied by the company because it can increase net income by 0.44% compared to initial net income and can reduce the amount of stockout that occurs so that customer satisfaction can be maintained. It can be done by the company by increasing the reorder point to 80 and the order quantity to 90. However, scenario 2 also makes the number of defective guitars higher. But the company does not need to worry, because the change in the number of guitars that are sold is more than the change in the number of defective guitars so that it will still increase the company's profits.

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