Inventory Simulation Modelling for Local Shoes Manufacturer

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Abstract

Covid-19 pandemic has made a major change in economic activities of small enterprises especially for local shoes manufacturers in Indonesia. The changing sales mechanism from purchase order to online sales has significantly decreased their income. The pattern of online demand is probabilistic in nature. It needs a dynamic model to manage inventory level. This research is aimed to build a simulation model in inventory management for local shoes manufacturer using Monte Carlo simulation to find an inventory policy that provide lower total cost. simulation. We use spreadsheet to construct the simulation model and observes 20 period of sales demand. We also calculate carrying cost, ordering cost, and stock out cost of raw materials, then we run 500 simulations. The objective function of simulation process is to minimize total cost of inventory. By changing the order quantity ranging from 20 to 700 units, the lowest inventory cost is reached when the order quantity is 100 meters when lead time is 1-2 days. The inventory cost has a u-shaped curve where the cost is high when the order quantity is below 100 meters and increases when the order quantity is above 100 meters. The simulation modelling inventory management provides useful tool in analyzing an order policy which minimizes inventory cost when the nature of demand is probabilistic.

Keywords
Spreadsheet simulation, inventory, stochastic model, Monte Carlo simulation and demand uncertainty

1. Introduction
Covid-19 pandemic has changed the way of business for local shoes manufacturers. Purchase order in large quantities are no longer available for due to lockdown in every aspect of activity including retail business sector. Sales mechanism of local shoes business has changed to online sales where demand is uncertain. Demand and lead time are not known with certainty in real business condition. According to (Taha, 2017), deterministic and constant in demand pattern is the least likely to occur in practice. Stochastic model provides effective solution when demand is subject to uncertainty (Deyi & Xiaoqian, 2017) and the most used optimization techniques for decision making under uncertainty (Soshko, 2011). Simulation is useful when demand and lead time are probabilistic (Render et al, 2018). Uncertain nature of demand in real business practice requires more complex analytical tool. Inventory is a complex problem that it is impossible to use the same mathematical model to fit all situations. Simulation is the alternative tool of modelling the situation (Taha, 2017). (Soshko, 2010) mentioned that simulation allows to test the effect of varying scenarios to select the best output performance.

1.1 Objectives

The aim of this research is to find the order quantity that minimizes total inventory cost using spreadsheet simulation model. The objectives are defined as follows:
(1) determine the inventory costs parameter of local shoes manufacturer business,
(2) develop a spreadsheet simulation models,
(3) run simulation model repeatedly across several quantity levels for different lead time scenarios,
(4) evaluate quantity ordered which provides the minimum total inventory cost,
(5) test pairwise compare mean of total inventory cost by varying the value of lead time.

2. Literature Review

The complexity of inventory models depends on the nature of demand whether it is deterministic or probabilistic (Taha, 2017). (Polanecky & Lukoszova, 2016) compiled publications of inventory models and discovers that stochastic models has the highest publications sources in which applicable to business practice.
(Bonilla-Enriquez & Caballero-Morales, 2020) use simulation model to evaluate the performance of dynamic inventory model for uncertain demand using open source programming software. (Tsai & Chen, 2016) employ simulation model to find reorder point and ordered quantity that minimizes inventory cost, average inventory level, and inventory shortage frequency. (Chu & You, 2014) apply simulation-based optimization to resolve multi echelon inventory problems. (Daniel & Rajendran, 2005) use simulation approach with the aid of genetic algorithm to optimize inventory level by minimizing total supply chain cost. (Khan & Chaabane, 2019) develop simulation model using Arena software to improve warehouse inventory management system. (Evans, 2000) reveals that simulation model involves several steps: (1) formulating the problem, determine the objective of simulation, the scenario to be evaluated, (2) develops logical model of the system analyzed, (3) establish probability distribution of input variables, (4) implementing the model to evaluate the model output.

Several research use a hybrid simulation and optimization approach to examine the behavior of inventory system. (Attar, Raissi, & Damghani, 2016) use Enterprise Dynamics simulation software to simulate the inventory model that customers' inter-arrival times, demand sizes, and lead times follows a probabilistic distribution and use mathematical optimization model to identify the optimal conditions. (Takeda-Bergern et al, 2018) use simulation-based optimization model in a pull-production system of a lean supply chain practices with the objective determining the optimum level of finished goods inventory and minimum production quantity of supplier company while keeping full-service level of the entire supply chain. (Al-Harkan & Hariga, 2007) develop simulation optimization model for continous review (Q,r) inventory system with lead time depending on lot size. (Xue et al, 2019) use simulation to model inventory problem using Discrete Event Simulation to examine the dynamics of the system as parameters change, such as replenishment time and quantity and optimization is employed using Particle Swarm Optimisation to identify the best result of parameter values combination.

Other studies carrying spreadsheet simulation to model a stochastic inventory problem because it is user friendly, easy to obtain, and can performs what if analysis (Zizka, 2005), (Shenoy & Mal, 2018). (Tiger et al, 2019) apply spreadsheet-based to evaluate the performance of supply chain simulation with inventory risk pooling. (Smith, 2003) suggests that spreadsheet modelling is very useful to analyze the impact of business decision on facility space, inventory investment and productivity. Spreadsheet simulation is often used when the model parameters could not be predicted or stochastic model (Seila, 2006). Spreadsheet model was used in various problems such as supply chain inventory simulation (Sezen & Kitapci, 2007), solving inventory problems for stochastic demand applied to bicycle shop (Widyadana et al, 2017), retail store (Leepaiton & Bunterngchit, 2019), pharmacy inventory management (Liu et al, 2013), fruit juice manufacturing firm (Mahamani et al, 2017), managing multiechelon inventory of repairable items (Shenoy & Mal, 2018).

Monte Carlo simulation uses random sampling to experiment on probabilistic elements that includes five steps: (1) establishing probability distributions for important input variable, (2) building a cumulative probability distribution for each variable, (3) establishing an interval for random numbers for each variable, (4) generating random numbers, (5) simulating a series of trials (Render et al, 2018). (Belvardi et al, 2012) employ Monte Carlo simulation to manage uncertainties and stochastic nature of the supply chains and to examine the relationship among decision variables and output performance. (Sabit et al, 2020) apply Monte Carlo simulation in inventory control system and compare company's current inventory model to inventory experiment model. The t-test similarity shows that their model has an accurate representation of the real system.

(Schriber, 2009) describes steps in conducting spreadsheet-based Monte Carlo simulation which involves built and test the model capturing the logic and relationship of the problem, designs input variables with uncertainty nature with probability distribution, record the observed value of output variable when the spreadsheet is recalculated, repeatedly recalculate in automated fashion, and process the sample value to provide information of the problem being modeled.

3. Methods

A spreadsheet simulation model is developed to capture the uncertainty in demand and lead time. Monte Carlo simulation model is used to generate demand simulation using normal probability distribution based on historical data. Similar method found in (Zabawa & Mielczarek, 2007), (Przasnyski, 1994), (Render et al, 2018) Mentioned that despite the complexity of inventory problem, all inventory situations share a common objective which is to minimize (setup cost + holding cost + shortage cost) (Taha, 2017). Then, the objective of simulation model is to minimize inventory cost consisting carrying cost, ordering cost, and stockout cost. Input variables defined in simulation consist of finished goods demand, unit carrying cost, ordering cost, stockout cost per unit, service level. Finished good demand is randomly generated by using probability distribution based on historical sales. Input variables are used to calculate reorder point by using the following equation: ROP = Average demand during lead time + $Z\sigma_{dLT}$ where Z is the number of standard deviations for a given service level, and σ_{dLT} is standard deviation during lead time**.**

4. Data Collection

Data are collected from field observation of local shoes manufacturer. Shoes demand is not known with certainty since the sales order comes from online sales and personal direct orders. This research explores main raw material in producing shoes which is leather. It requires 1 meter of leather to produce 20 pair of shoes. Carrying cost of leather is estimated from the percentage of scrapped materials. The ordering cost is estimated from the transportation cost incurred to acquire raw materials. Stock out cost is estimated from the minimum selling price per unit of shoes.

5. Results and Discussion

5.1 Spreadsheet Simulation Model

Figure 1 presents the input variables to calculate reorder point and raw materials order quantity. Spreadsheet simulation model begin with inventory variable decision section. The input variables for order quantity decision are carrying cost per unit, ordering cost, and stockout cost. In determining reorder point, input variables are service level, lead time, average and standard deviation of raw material demands during lead time. The objective of simulation model is to minimize total inventory cost which is the sum of carrying cost, ordering cost, and stockout cost.

Inventory Decision Variables

Service Level	Minimum Lead Time	Maximum Lead Time	Average Demand of Raw Materials	Std. Deviation Demand of Raw Materials	**Reorder point**	Carrying cost per unit	Ordering cost	Stockout cost	**Order Quantity**
95%	1.00	2.00	2.03	2.82	**9**	0.0013	3.15	8.62	**40.00**

Objective Parameters (USD)

Carrying	Ordering	Stockout	Total Cost
0.65	**6.61**	**37.81**	**45.07**

Figure 1: Input Variables and Objective Parameters

For the purposes of simulation proses, probability distribution is established to generate input variable which is finished good demand as presented in Table 1. We use demand distribution method found in (Przasnyski, 1994), (Render et al, 2018), (Zizka, 2005). Finished good demand is converted to generate raw material demand.

Table 1: Demand Probability Distribution

Demand of Finished Good	Frequency	Probability	Random Numbers	
			Lower Limit	Upper Limit
0	20	0.3333	0	0.3333
20	20	0.3333	0.3333	0.6667

Demand of Finished Good	Frequency	Probability	Random Numbers	
			Lower Limit	Upper Limit
40	10	0.1667	0.6667	0.8333
60	5	0.0833	0.8333	0.9167
80	5	0.0833	0.9167	1.0000
	60			

Figure 2 presents the simulation spreadsheet model. The simulation process is calculated one day at a time. The first step begins each day by checking whether any order received. If it has, it would increases the available inventory by the quantity ordered plus beginning inventory. Demand of finished goods is generated, then it is converted to raw material demand. Fulfilled demand calculates the minimum values between available inventory and demand of raw materials. When demand of raw materials is fulfilled, it will reduce ending inventory of the same amount. Stockout occurs when raw material demand could not be fulfilled. The column of ending inventory plus order tracks the amount of raw materials inventory whether it reaches below reorder point. When the quantity of raw material reaches reorder point, then an order must be placed. Due to the uncertain condition in lead time, we conducted simulation of three kinds of lead time which are 1-2 days, 1-3 days, and 1-4 days. We generate random numbers for lead time between the minimum and maximum numbers of days in lead time provided in Figure 1. The three last columns calculate the cost components of total inventory cost. Carrying cost is carrying cost per unit multiply by the amount of ending inventory. Ordering cost occurs only when an order is placed times ordering cost. Stockout cost occurs only when there is stockout, by multiplying the amount of stockout by stockout cost per unit.

Simulation Process

Days	Beginning Inventory	Order Received	Available Inventory	Demand of Finished Good	Demand of Raw Material	Fullfilled Demand	Ending Inventory	Stockout	Ending Inventory + Order	Place Order		Lead Time	Order arrived at period t	Inventory Cost			
														Carrying Cost	Ordering Cost	Stockout Cost	Total Cost
1	0	0	0	0	0	0	0	0	0	1	Ordrer	2.00	3	-	3.15	-	3.15
2	0	0	0	80	9	0	0	9	73	0	No	2.00	0	-	-	77.59	77.59
3	0	73	73	20	2	2	71	0	71	0	No	3.00	0	0.09	-	-	0.09
4	71	0	71	0	0	0	71	0	71	0	No	3.00	0	0.09	-	-	0.09
5	71	0	71	0	0	0	71	0	71	0	No	1.00	0	0.09	-	-	0.09
6	71	0	71	80	9	9	62	0	62	0	No	3.00	0	0.08	-	-	0.08
7	62	0	62	40	5	5	57	0	57	0	No	3.00	0	0.07	-	-	0.07
8	57	0	57	0	0	0	57	0	57	0	No	2.00	0	0.07	-	-	0.07
9	57	0	57	0	0	0	57	0	57	0	No	1.00	0	0.07	-	-	0.07
10	57	0	57	20	2	2	55	0	55	0	No	2.00	0	0.07	-	-	0.07
11	55	0	55	0	0	0	55	0	55	0	No	3.00	0	0.07	-	-	0.07
12	55	0	55	80	9	9	46	0	46	0	No	1.00	0	0.06	-	-	0.06
13	46	0	46	0	0	0	46	0	46	0	No	3.00	0	0.06	-	-	0.06
14	46	0	46	0	0	0	46	0	46	0	No	2.00	0	0.06	-	-	0.06
15	46	0	46	0	0	0	46	0	46	0	No	2.00	0	0.06	-	-	0.06
16	46	0	46	0	0	0	46	0	46	0	No	1.00	0	0.06	-	-	0.06
17	46	0	46	0	0	0	46	0	46	0	No	1.00	0	0.06	-	-	0.06
18	46	0	46	0	0	0	46	0	46	0	No	1.00	0	0.06	-	-	0.06
19	46	0	46	20	2	2	44	0	44	0	No	1.00	0	0.06	-	-	0.06
20	44	0	44	20	2	2	42	0	42	0	No	3.00	0	0.05	-	-	0.05
													Total Cost	**1.26**	**3.15**	**77.59**	**82.00**

Figure 2: Spreadsheet Simulation Model

After calculating the total inventory cost, the spreadsheet simulation is extended to 500 simulation of total inventory cost presented in Figure 3. The simulation process is prerequisite step to run what if analysis at each order quantity level and lead times. Number of replications found in previous studies were various ranging from 30 runs (Soshko, 2010), 60 runs (Zabawa & Mielczarek, 2007), to 1000 runs (Render et al, 2018), (Chu & You, 2014). The simulation is run by varying the values of two variable parameters: (1) order quantity ranging from 20 meters, 40 meters, 50 meters, 60 meters, 80 meters, 100 meters, 200 meters, and 700 meters to find the quantity ordered which has the minimum cost, and (2) lead time of 1 to 2 days, 1 to 3 days, and 1 to 4 days. The simulation is aimed to compare total inventory cost among various lead time on all order quantity levels. The result of simulation calculation is summarized in Table 2.

Run Simulation	Carrying Cost	Ordering Cost	Stockout Cost	Total Cost
1	0.64	6.30	-	6.94
2	0.57	6.30	81.9	88.76
3	0.77	6.30	58.19	65.25
4	0.61	6.30	38.79	45.7
5	0.69	9.44	-	10.13
496	0.76	6.30	77.59	84.64
497	0.59	9.44	-	10.03
498	0.47	3.15	38.79	42.41
499	0.68	6.30	-	6.98
500	0.60	3.15	-	3.75

Figure 3: Simulating Total Inventory Cost

5.2 Spreadsheet Simulation Results

Spreadsheet simulation calculation summary presented in Table 2, reveals that the longer the lead time required to acquire raw material, the higher the total inventory cost incurred. Higher inventory cost is due to higher stockout cost, while carrying cost and ordering cost are lower as lead times become longer at all quantity levels. Minimum inventory cost incurred at different quantity of ordered raw materials depends on lead time required. When lead time required 1-2 days, the minimum inventory cost reaches at 100 meters of ordered raw materials. Longer lead time of more than 1-2 days, the minimum inventory cost occurred at lower ordered raw material of 60 meters.

Table 2: Inventory Cost Simulation with Probabilistic Lead Time and Demand

Lead time	Inventory Cost	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
		20	40	50	60	80	100	200	700
1 – 2 days	Carrying Cost	0.38	0.64	0.78	0.90	1.28	1.77	4.15	16.31
	Ordering Cost	11.35	6.45	5.66	4.93	3.46	3.15	3.15	3.15
	Stockout Cost	38.58	34.42	35.99	35.86	35.61	37.44	36.47	33.44
	Total Cost	46.83	42.55	41.57	43.29	41.17	39.88	44.39	57.95
1 – 3 days	Carrying Cost	0.40	0.65	0.77	0.90	1.26	1.73	4.08	15.85
	Ordering Cost	11.57	6.52	5.73	5.19	3.61	3.18	3.15	3.15
	Stockout Cost	49.52	52.48	47.94	48.54	49.42	48.26	48.61	49.46
	Total Cost	63.74	57.94	59.32	50.54	55.44	53.75	57.38	67.13
1 – 4 days	Carrying Cost	0.42	0.66	0.79	0.90	1.25	1.71	4.00	15.44
	Ordering Cost	11.76	6.66	5.85	5.07	3.71	3.17	3.15	3.15
	Stockout Cost	64.23	60.69	59.55	60.23	61.10	62.34	59.94	61.76
	Total Cost	74.31	69.39	66.12	65.71	66.87	66.18	65.80	81.46

The result suggests that raw material should be ordered at quantity of 100 meters when lead time is 1-2 days. When lead time is1-3 days or 1-4 days, then the quantity of raw materials ordered should be 60 meters. Lower or higher amount of raw material ordered would cause higher total inventory cost. It also implies that ordering small amount of raw material to fulfill small batch order of finished goods is not efficient.

5.3 Proposed Improvements

Total inventory cost of each lead time scenarios is plotted on all quantity levels in Figure 4. Longer lead time leads to higher total inventory cost within all quantity levels. Total inventory cost is highest when lead time is 1-4 days. A decrease in lead time leads to decrease in total inventory cost. Similar finding found in (Goyal & Satir, 1989) where cost savings increase when lead time decrease. Lowest inventory cost achieved when lead time is 1-2 days. It implies that lead time should be a major consideration in shoe manufacture business since it could affect cost efficiency.

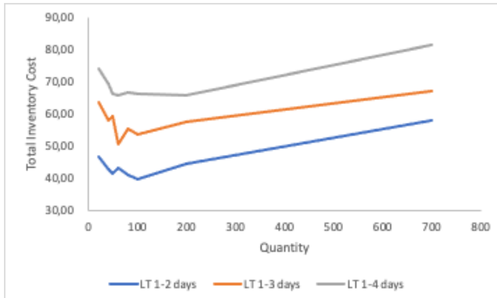

Figure 4: Total Inventory Cost at Different Lead Times

5.4 Hypothesis Testing

We use two pairwise comparation means to test whether total inventory cost is considerably different among various lead times stated in the following hypothesis:
H1: total inventory cost differs considerably in terms of 1-2 days lead time and 1-3 days lead time
H2: total inventory cost differs considerably in terms of 1-2 days lead time and 1-4 days lead time
H3: total inventory cost differs considerably in terms of 1-3 days lead time and 1-4 days lead time

Table 3: Pairwise Test of Inventory Cost

	1-2 days	*1-3 days*	*1-2 days*	*1-4 days*	*1-3 days*	*1-4 days*
Mean	45.72	58.26	45.72	69.58	58.26	69.58
Variance	28.08	26.45	28.08	24.29	26.45	24.29
Observations	12	12	12	12	12	12
t Stat	-13.19		-36.92		-15.66	
P(T<=t) two-tail	0.00%		0.00%		0.00%	

Table 3 presents the summary of pairwise test of inventory cost. This finding shows that total inventory costs differ considerably among various lead times. The lower the lead time, the lower total inventory cost. Longer lead time will cause inefficiency in inventory cost. Then lead time is a critical variable to consider in cost efficiency.

H1: total inventory cost differs considerably in terms of 1-2 days lead time and 1-3 days lead time
We find that inventory cost of 1-2 days lead time amounting US$ 45.72 is significantly lower than the inventory cost with 1-3 days lead time amounting US$ 58.26.
H2: total inventory cost differs considerably in terms of 1-2 days lead time and 1-4 days lead time
We find that inventory cost of 1-2 days lead time amounting US$ 45.72 is significantly lower than 1-4 lead time amounting US$ 69.58.
H3: total inventory cost differs considerably in terms of 1-3 days lead time and 1-4 days lead time
Inventory cost of 1-3 days lead time amounting US$ 58.26 is significantly lower than the inventory cost of 1-4 days lead time which amount US$ 69.58.

6. Conclusion

Uncertainty in demand is a common nature in business practice. It requires a more complex model in inventory model to provide an effective decision making. Spreadsheet simulation model provide a useful information to estimate order quantity with minimum total inventory cost. The simulation model suggest that lead time has considerable effect on total inventory cost. Longer lead time would cause higher total inventory cost due to higher stockout cost. The difference of total minimum cost in terms of lead time is significant.

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