



Inventory Simulation-Optimization Model for Small Business

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Abstract

Simulation-optimization inventory models are widely used in inventory management studies, including for perishable good. A good inventory management is required to save inventory cost. We use simulation approach to take into consideration of uncertain demand and lead time to obtain a better result of optimal order quantity that minimizes inventory cost. Simulation result shows that simulation-optimization models generates lower total inventory cost. The simulation provides information of objectives in inventory management: (1) how much to order and (2) when to order with minimum cost which gives valuable information in business decision making.

Keywords: economic order quantity, inventory management, simulation-optimization, perishable inventory

1. Introduction

We conduct a study of inventory management in a fried shallot home industry. Shallot as the main raw material in producing fried shallot is quite a challenging task. It needs a certain temperature to maintain its quality. It can not be stored for a longer period of time because it will deteriorate the weights up to 16,22% (Amiarsi, Sasmitaloka, Arif, & Widayanti, 2019). Another problem that occur is the price of raw material often fluctuates. By buying large quantity of raw materials when the price is low, will create overstocking. Overstocking will reduce the quality of raw materials which will cause a low quality of final product. A perishability of a product is a significant problem in food industry and need a good inventory management to save the wastage (Duong, Wood, & Wang, 2015).

On the other hand, keeping too low of the inventory will require higher cost because of more frequent order. Good quality shallots are purchased from Brebes, Central Java that located 323 km away from where the business location. The purchasing of raw materials requires a high transportation cost. Frequent order will cause a high ordering cost. In addition, inadequate level of inventory will cause a shortage cost due to lost sales. Thus, a balance should be made among inventory cost which includes ordering cost, carrying cost, and shortage or stock out cost. By minimizing all of these inventory cost as objective function in optimization model, the optimal level of inventory could be determined.

2. Materials and Methods

2.1. Materials

Fried shallot home industry is a small business located in Bogor, West Java, Indonesia and owned by a local entrepreneur. The business started in 2016 with sales amounting USD 400 to USD 600 per month. The price of fried shallot is USD 2 per pack. It would take one kilogram of shallot to make one pack of fried shallot. Each pack contained 250 grams of fried shallot.

We use the quantity of sales of fried shallots and shallot purchased in analyzing the raw materials inventory. The inventory model developed in this study focus on shallot as the main raw material used in production. A spreadsheet simulation model is developed to analyze the inventory process and calculate the component of inventory cost, which includes carrying cost, ordering cost, and shortages cost. After simulation process completed. Then, we used Excel Solver to determine the optimal level of raw material inventory by minimizing total inventory cost as objective function. Economic order quantity is also calculated to compare the optimal order quantity obtained from the simulation model.

2.2. Methods

Combined the simulation and optimization method for multi-echelon inventory system studies are found in (Xu, Feng, Chen, Wang, & Wang, 2019), (Kochel & Nielander, 2005), (Duan & Liao, 2014). The inventory analysis comprises of three phases. Phase 1, we analyze the demand of finished good and quantity purchased of one main raw materials, which is shallot. We observe 20 days of sales and raw materials purchase activities to construct simulation analysis. Sales of fried shallots for one month have a range of USD 400 to USD 600. It requires a raw materials of shallots amounting 222 kg per month.

The essential part in developing inventory management model is the identification of inventory cost, which consists of ordering cost and carrying cost. The components of inventory cost analyze in this study consists of ordering cost, carrying cost, and shortage cost. Ordering cost are cost which related to the purchasing activity of raw materials. In this study, transportation cost in delivering shallots and telephone bills are considered as ordering cost.

Carrying cost is calculated from the deteriorating value of shallot when it is stored as inventory. Based on study of (Purwanto & Pujantoro, 2017) that weight of shallots will be lost at a range 15% to 20% at room temperature for one week storage. Another study finds that shallot weight loss at a range 16,22% to 19,2% at room temperature for 6 day storage (Amiarsi, Sasmitaloka, Arif, & Widayanti, 2019). (Bakker, Riezebos, & Teunter, 2012) mentioned that there are three models of deteriorating inventory based on shelf life characteristics: (1) fixed lifetime, (2) age dependent deterioration rate, (3) time or inventory dependent deterioration rate. We use these the third model of deteriorating inventory classification to estimate the potential loss of shallot value by 18% from the purchase cost per unit (Tosida et al., 2016; 2017).

The shortage cost is the potential loss of income when stock is out (Taha, 2017). We calculate the potential loss by converting the unit price per gram of final product, then multiply by the conversion rate of raw material required to produce one gram of final product. All of the component cost of inventory are provided in Figure 2 at the section of F16, G16, H16.

After ordering cost (C_o), carrying cost (C_h), and demand for period of analysis (D) are identified, the economic order quantity can be calculated by the following formula:

$$EOQ = \sqrt{(2 \cdot D \cdot C_o) / C_h} \quad (1)$$

We proceed to calculate the reorder point (ROP). Reorder point is calculated by adding the average demand during lead time (dL) and safety stock (SS). The formula used to find reorder point is:

$$ROP = \bar{d}L + \text{Safety stock} \quad (2)$$

Safety stock is calculated by assuming the service level maintained. Service level is a percentage of the time customer demand is met (Render, Stair, Jr., Hanna, & Hale, 2018). As mentioned in (Donselaar & Broekmeulen, 2012) a service level at a range of 90% to 98% is reasonable for many regular perishable grocery products, we use 95% as the service level to determine Z value as the component parameter in determining safety stock (ss). Thus, the safety stock (ss) in MS Excel is calculated with the following formula (Chopra & Meindl, 2016):

$$ss = NORMSINV(CSL) \times \sigma_L \quad (3)$$

CSL is cycle service level, and σ_L is standard deviation of demand during lead time. The Z value of service level can be obtained in MS Excel by using NORMSINV. When we use 95% of service level, MS Excel can automatically convert the probability of service level to Z value of 1,65.

Phase 2, we conduct inventory management modelling by constructing a spreadsheet simulation model. Simulation is a powerful tool to evaluate the impact of business decisions on performance in uncertain environment (Chopra & Meindl, 2016). Simulation approach in managing inventory were also found in several studies such as (Liu, Zhang, Liu, & Lin, 2013), (Soshko, Vjaks, & Merkuryev, 2010), (Mahamani, Rao, & Pandurangadu, 2017), (Duong, Wood, & Wang, 2015), (Badri, 1999), and (Alstrom & Madsen, 1992). The advantage of simulation is useful when demand and lead time are probabilistic (Render, Stair, Jr., Hanna, & Hale, 2018). The simulation model allows the inclusion of variability in demand and lead time.

Before begin the simulation process, we have to calculate the input parameters which are divided into two categories: (1) inventory cost components, and (2) reorder point (ROP) components. Inventory cost components are carrying cost per unit, ordering cost, and stock out cost. Reorder point components are lead time and service level. The simulation process starts with beginning inventory in column B which represents the inventory available before production process begin. Column C records order received based on the information order placed in column K and lead time period in column L. Column D represents available inventory by summing column B and column C. Column E is number of raw material demand required for the period. Column F represent fulfilled demand which will take the minimum amount between column D and column E. When available inventory is larger than demand, it means that demand is fulfilled. Column G represent ending inventory calculated by subtracting column D to column F. Column H represent number of stock out units that occurs when fulfilled demand is zero. Column I represents the ending inventory after demand is fulfilled and order received. Column J use information provide in column J to create code of 1 if Column J is lower than reorder point, and otherwise 0. Code 1 means that an order should be placed which is stated in Column K. Column L is lead time period required to receive raw materials. Column M represents the period in which an order will arrive. Column N represents carrying cost by multiplying column G with carrying cost per unit at cell F16. Column O represents ordering cost by multiplying column J with ordering cost at cell G16. Column P represents stock out cost by multiplying column H with stock out cost at cell H16. Column Q represents total cost which is the sum of carrying cost, ordering cost and stock out cost.

At phase 3, we determine the optimal order quantity using Ms Excel Solver. The objective value is to minimize the average total cost with the following formula:

$$\text{Minimize}(\text{orderring cost} + \text{carrying cost} + \text{stock out cost}) \quad (4)$$

Minimum total cost is the performance measure of the inventory simulation-optimization model. (Beshara, El-Kilaney, & Galal, 2012) use simulation model to evaluate and analyse the performance of two echelon production and distribution supply chain system for agri-food products based on inventory cost components performance, such as purchasing cost, cost of waste, cost of selling in open market, holding cost, transportation cost, and total cost.

3. Results and Discussion

Figure 1 represents the spreadsheet simulation model using economic order quantity to obtain the optimal order quantity. The EOQ model gives higher optimal higher order quantity represented at cell A16. Due to high cost in ordering raw materials, then EOQ model suggest only one time in placing an order. It will generate overstocking which has the implication to high carrying cost. Since shallot is a perishable good, overstocking will deteriorate the quality of raw materials. The carrying cost in this case is the loss of economic value of deteriorating raw materials.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
14	EOQ	Service level	Reorder point	Minimum Lead Time	Maximum Lead Time	Carrying cost per unit	Ordering cost	Stockout cost	Optimized Order Quantity					Carrying Cost	Ordering Cost	Stockout Cost	Total Cost	
15																		
16	254	95%	13	1.00	2.00	3,780	550,000	400	254.30					AVERAGE	13,337,532	550,000	3,966	13,891,498
17																		
18																		
19	Days	Beginning Inventory	Order Received	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Ending Inventory + Order	Place Order	Lead Time	Order arrived at period t		Carrying Cost	Ordering Cost	Stockout Cost	Total Cost	
20	1	0	0	0	2	0	0	2	0	1 Order	1	2		-	550,000	800	550,800	
21	2	0	254	254	13	13	241	0	241	0 No	2	0		912,109	-	-	912,109	
22	3	241	0	241	4	4	237	0	237	0 No	2	0		896,989	-	-	896,989	
23	4	237	0	237	7	7	230	0	230	0 No	2	0		870,529	-	-	870,529	
24	5	230	0	230	7	7	223	0	223	0 No	2	0		844,069	-	-	844,069	
25	6	223	0	223	10	10	213	0	213	0 No	2	0		806,269	-	-	806,269	
26	7	213	0	213	7	7	206	0	206	0 No	1	0		779,809	-	-	779,809	
27	8	206	0	206	6	6	200	0	200	0 No	2	0		757,129	-	-	757,129	
28	9	200	0	200	1	1	199	0	199	0 No	2	0		753,349	-	-	753,349	
29	10	199	0	199	5	5	194	0	194	0 No	1	0		734,449	-	-	734,449	
30	11	194	0	194	11	11	183	0	183	0 No	1	0		692,869	-	-	692,869	
31	12	183	0	183	9	9	174	0	174	0 No	2	0		658,849	-	-	658,849	
32	13	174	0	174	4	4	170	0	170	0 No	2	0		643,729	-	-	643,729	
33	14	170	0	170	1	1	169	0	169	0 No	1	0		639,949	-	-	639,949	
34	15	169	0	169	13	13	156	0	156	0 No	2	0		590,809	-	-	590,809	
35	16	156	0	156	10	10	146	0	146	0 No	2	0		553,009	-	-	553,009	
36	17	146	0	146	4	4	142	0	142	0 No	1	0		537,889	-	-	537,889	
37	18	142	0	142	8	8	134	0	134	0 No	2	0		507,649	-	-	507,649	
38	19	134	0	134	8	8	126	0	126	0 No	2	0		477,409	-	-	477,409	
39	20	126	0	126	4	4	122	0	122	0 No	1	0		462,289	-	-	462,289	
40														Total Cost	13,119,155	550,000	800	13,669,955

Figure 1: Spreadsheet Simulation Model with EOQ

We use the simulation optimization model to compare the performance of total cost generated by both model. The optimal order quantity is found by using Excel Solver by running all the 500 simulation that has been build in phase 2. Cell I16 is a decision variable of optimal order quantity. It is the quantity to be ordered suggested by the simulation-optimization model after minimizing total inventory cost. The simulation model also gives the information of how many quantity to order and when to order.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
14	EOQ	Service level	Reorder point	Minimum Lead Time	Maximum Lead Time	Carrying cost per unit	Ordering cost	Stockout cost	Optimized Order Quantity					Carrying Cost	Ordering Cost	Stockout Cost	Total Cost	
15																		
16	254	95%	14	1.00	2.00	3,780	550,000	400	44					AVERAGE	1,827,953	1,940,400	4,350	3,772,703
17																		
18																		
19	Days	Beginning Inventory	Order Received	Available Inventory	Demand	Fulfilled Demand	Ending Inventory	Stockout	Ending Inventory + Order	Place Order	Lead Time	Order arrived at period t		Carrying Cost	Ordering Cost	Stockout Cost	Total Cost	
20	1	0	0	0	10	0	0	10	0	1 Order	1	2		-	550,000	4,000	554,000	
21	2	0	44	44	13	13	31	0	31	0 No	1	0		118,286	-	-	118,286	
22	3	31	0	31	13	13	18	0	18	0 No	1	0		69,146	-	-	69,146	
23	4	18	0	18	12	12	6	0	6	1 Order	2	6		23,786	550,000	-	573,786	
24	5	6	0	6	8	8	0	2	44	0 No	2	0		-	-	683	683	
25	6	0	44	44	8	8	36	0	36	0 No	2	0		137,186	-	-	137,186	
26	7	36	0	36	1	1	35	0	35	0 No	1	0		133,406	-	-	133,406	
27	8	35	0	35	2	2	33	0	33	0 No	2	0		125,846	-	-	125,846	
28	9	33	0	33	6	6	27	0	27	0 No	2	0		103,166	-	-	103,166	
29	10	27	0	27	10	10	17	0	17	0 No	1	0		65,366	-	-	65,366	
30	11	17	0	17	8	8	9	0	9	1 Order	1	12		35,126	550,000	-	585,126	
31	12	9	44	54	11	11	43	0	43	0 No	2	0		160,973	-	-	160,973	
32	13	43	0	43	1	1	42	0	42	0 No	2	0		157,193	-	-	157,193	
33	14	42	0	42	10	10	32	0	32	0 No	2	0		119,393	-	-	119,393	
34	15	32	0	32	7	7	25	0	25	0 No	2	0		92,933	-	-	92,933	
35	16	25	0	25	5	5	20	0	20	0 No	2	0		74,033	-	-	74,033	
36	17	20	0	20	0	0	20	0	20	0 No	1	0		74,033	-	-	74,033	
37	18	20	0	20	7	7	13	0	13	1 Order	2	20		47,573	550,000	-	597,573	
38	19	13	0	13	12	12	1	0	45	0 No	2	0		2,213	-	-	2,213	
39	20	1	44	45	3	3	42	0	42	0 No	1	0		158,299	-	-	158,299	
40														Total Cost	1,697,957	2,200,000	4,683	3,902,640

Figure 2: Spreadsheet Simulation-Optimization Model of Inventory Management

The total cost of economic order quantity model has generated a higher cost than simulation-optimization model. Optimal order quantity is measured in units and the cost of inventory and its components are measured in Indonesian currency (Rupiahs). The total cost comparison of both model presented in table below.

Table 1: Total Inventory Cost Comparison

Model	Optimal Order Quantity (kg)	Carrying Cost (Rp.)	Ordering Cost (Rp.)	Stock Out Cost (Rp.)	Total Cost (Rp.)
EOQ	254	13.333.081	550.000	3.904	13.886.985
Simulation-optimization	44	1.827.953	1.940.400	4.350	3.772.703

Economic order quantity results in higher carrying cost which has the largest value of the cost components. Although the economic order quantity suggests only one in order taking, but the carrying cost generate a very high cost. It shows that overstocking would create a significant high cost because of the decreasing value caused by weight loss shallots stored in room temperature. The simulation-optimization model provides much lower cost of inventory. The model suggests more frequent order with lower carrying cost in significant amount as a trade off.

4. Conclusion

We compare two model of optimization in inventory management subject to minimizing the total cost of inventory. The result shows a huge different in inventory cost. The simulation-optimization model generates much lower inventory cost. The characteristics of raw materials should be taken into consideration in inventory management. In the case of this study, shallots as the raw material would loss of its weights when stored in room temperature. Therefore, overstocking raw materials will produce very high carrying cost. Simulation-optimization model provides another advantages that the simulation process takes into account the variability of demand and lead time in calculating the optimal order quantity at the minimum cost. The simulation-optimization model also gives the information of two objectives in inventory management: (1) how much to order, and (2) when to order.

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