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Research article

Optimizing costs for vaccine control using the reorder point approach

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ABSTRACT

Vaccines are biological products that have an important role in human immunity. In Indonesia, some vaccines are categorized as compulsory vaccines and additional vaccines. The demand for additional vaccines is less predictable because they are not mandatory for use. This of course makes the amount of demand for vaccines less predictable. Also, the price of additional vaccines is not cheap when compared to the price of mandatory vaccines. So that the management of vaccines in the pharmacy warehouse is needed so that the amount of supply and demand is balanced so that the costs incurred will be more optimal. The information system regarding vaccine reordering is carried out using a reorder point so that the pharmacy warehouse can order according to the right need and at the right time. The data used are demand data, prices, storage costs, and message costs. The results of calculations using reorder points within four months with a total purchase for the Rotavirus vaccine was 62 for IDR 28,274,948 and 70 for the hospital of IDR 31,801,500 with a difference of IDR 3,528,552. The calculation result using the reorder point for the Hexaxim vaccine with a total purchase for 4 months was 61 with a nominal value of IDR 58,380,060 while the calculation in the hospital was 67 with a nominal value of IDR 63,971,000 so that a nominal difference of IDR 5,590,940 was obtained. Use of the return point can be used to alarm when and how many vaccines to order. This can be seen from the cost difference between the pharmacy warehouse and the calculation using the reorder point for the Hexaxim vaccine and the Rotavirus vaccine.

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1. Introduction

An empty vaccine for the hospital will adversely affect both the patient and the hospital. In addition to undisturbed services, hospital income will also have an impact because it cannot be denied that patients will meet the vaccine needs of other hospitals. Inventory control is very important to be managed in a supply chain. Good inventory management so that consumer needs can be met and can avoid inventory vacancies in pharmaceutical warehouses. In inventory management, there are waiting times, costs arising from ordering, maintaining goods, and storage [1].

In hospitals, the need for drugs, vaccines, and other health needs is provided by the pharmacy department. If the hospital develops, the need for drugs, vaccines, and other medical devices will automatically increase. and automatic, and the biggest costs are from the pharmacy. The need for drugs, vaccines, and other medical devices will increase along with the development of a hospital. Vaccination

is a method used to prevent disease outbreaks. Efficiency and level of customer service are important components in the supply chain [2]. In the hospital, the need for medicine, vaccines, and other health needs is provided by the pharmacy department. Control of the amount of vaccine stock is one of the important criteria in supply management [3]. Vaccines are a special type of drug whose quality is very susceptible to temperature [4].

In Indonesia, there are several types of vaccines, namely mandatory vaccines and recommended vaccines. For mandatory vaccines, of course, it is a little easier to see the number of requests. The recommended vaccine has a price that is not cheap, different from the mandatory vaccine. The Rotavirus vaccine and the Hexaxim vaccine are examples of the recommended vaccines. For types of vaccines that are not required by the government but are advised to have difficulties predicting the amount of demand so that supply management is needed to aim that the number of vaccines available in the pharmaceutical department is continuously fulfilled but under control.

In a supply chain system, besides being important for managing supplies, it is also essential for forecasting changes in demand in supplies [5]. Changes in demand are a problem that often occurs in the supply system [6] besides, the uncertainty of the number of requests and delays in delivery are also problems in the supply chain [7]. The challenge faced in managing supply is that there is a demand that exceeds the amount of reserve, which can cause a shortage of stock [8].

The supply chain, arrangements are required to determine how much safety stock is needed to face uncertain demand [9]. In the pharmaceutical warehouse, stock replenishment is carried out based on a certain amount that has been previously determined without considering the actual amount of vaccine needed. This of course impact on the costs that will be incurred for the procurement of vaccines such as order vaccines, saving cost, and ordering fee.

Several methods are used to control the amount of inventory, one of which is the reorder point. The purpose of inventory control is to manage the list and renewal of goods at the central warehouse by calculating minimal costs in the supply chain based on consumer demand [10]. The solution offered with the needs of pharmaceutical warehouses is how to control the procurement of vaccines by using reorder points and safety stock so that later you can find out when is the right time to reorder so it can optimize costs incurred by pharmaceutical warehouses.

The reorder point is a method that can be used to analyze inventory control by balancing the amount of supply and demand [11]. The number of vaccine requests recommended by the number of mandatory vaccine requests is very different. So that the wrong amount of vaccine purchases can affect storage space, the costs used to buy vaccines and the cost of ordering vaccines [12]. In addition, if the amount of supply is not managed properly, it will disrupt demand from consumers. For the estimated average amount of use and avoiding out-of-stock, safety stock is used as a limit [13]. To control the inventory is done by determining how many safety stocks and to reorder points are based on the system's sales data [7]. This research is intended to control the supply of vaccines with reorder points to make costs more optimal, and the determination of reorder points in each supply system is highly recommended so that the costs arising from vaccine supply can be optimized.

2. Related Work

In existing research, it is stated that supply management is still using stock cards whose standard procedures are not carried out properly, which can lead to inadequate vaccine supplies [10]. Control of an inventory has an important role in monitoring the condition of goods. For controlling inventory, it is calculated by minimizing costs in the supply chain. So that the inventory control system can optimize supply chain costs [14].

The calculation of the initial order point is a starting point in determining when is the right time to place an order by taking into account the increase in the manufacture of goods, waiting time, and system costs to maximize efficiency and profit from the system. Additionally, to get the batch size taking into account the costs incurred on the system. However, the extension of this study is to obtain the optimal batch size by considering the costs incurred for the system by the safety stock [11].

Order quantity and reorder points are two major challenges in supply chain management. The reorder point as well as the number of orders, can increase the overall supply chain advantage with the uncertainty of the number of requests and waiting times [13]. The application of technology into the

supply chain in a supply chain management can make an optimal decision regarding the number of refills and reorder points which will be used to minimize the costs used for supplies [15].

In supply management with a supply chain environment with a seasonal amount of demand requires an appropriate selection. The effect of capacity on the number of orders and the reorder point inventory control model has been followed by lead time requests and repeated solutions to obtain optimal solutions regarding the problem of order quantity or reorder point, optimization, and limits on the choice of order quantities and reorder points [16].

In making decisions with uncertainty and the consequences that will occur, all quantitative and qualitative information must be available because the calculations carried out for testing are low in demand so that the results obtained can be used to solve the problem of costs that exist in the supply chain [17].

3. Method

Vaccines are very vulnerable and their storage requires special treatment so that the vaccine is not damaged. Controlling the number of vaccines can not only affect the pharmacy department but also affect the budget that will be spent [18]. The data input process is obtained from pharmacy warehouses, namely vaccine needs, vaccine ordering costs, service costs, vaccine prices, and vaccination requests.

Then from the data that has been inputted then determine the lead time then calculate the safety stock, Reorder Point, and Economic Order Quantity (EOQ) of the framework information flow as in Fig. 1.

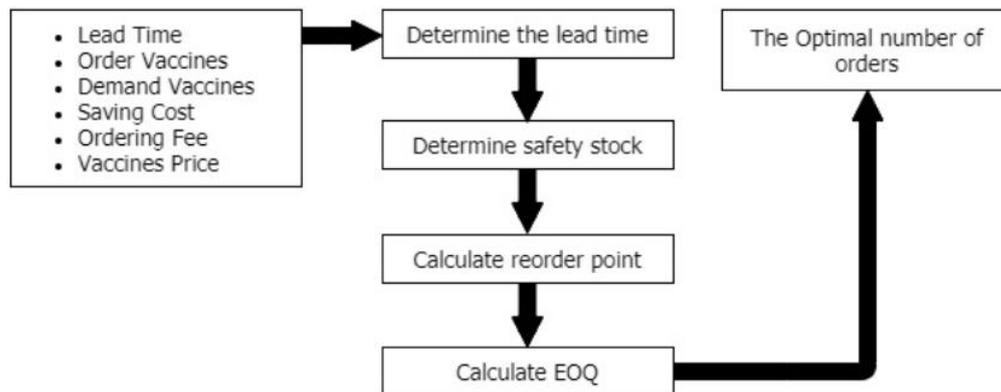


Fig. 1. Information systems framework

Control of the number of vaccines in the hospital is used in order there is no shortage and excess of vaccine stock. Other than that, the costs used will be more optimal and supply chain activities vaccines at the pharmacy do not experience interruptions in service in-hospital patients. So that the amount of safe inventory can be done by calculating through sales data so that the amount of inventory will be optimal [19].

3.1. Lead time

Lead time is the time needed between orders and goods that arrive in the warehouse [20], this time appears because when the order is placed it does not automatically exist so it requires a time lag in delivery. The lead time is constant, but the lead time varies to anticipate it, so safety stock is needed.

3.2. Safety stock

Safety stock (SS) is an additional amount of inventory that is used to avoid inventory void and order lead time. The goal is to protect inventory from several things such as delivery time, types of needs, number of shipments, and inventory variations. The equation used to obtain safety stock is like Eq. 1 [21],

$$SS = Z \times \sigma LTD \quad (1)$$

where SS is the safe stock, Z is the service factor and σLTD is the standard deviation. To get the service factor value on the safety stock calculation as in Table 1.

Service level is used in inventory management to be a measure of the performance of an inventory rule in the pharmaceutical department and can represent the possibility of not experiencing out of stock and not losing vaccine sales. Service levels and safety stock supplies can be controlled more effectively using standard deviations. The determination of the safety stock is used by considering the deviations

that have occurred between the user estimates so that the standard deviation is known and the safety factor shows how many standard deviations correspond to a specific Service level [22]. Meanwhile, to find the standard deviation value, Eq. 2 is used as follows,

$$\text{Standard deviation } (\sigma) = \sqrt{\frac{\sum_{i=1}^{19} (x_i - x)^2}{n-1}} \tag{2}$$

where x_i is the demand data i , and x is the demand average, and n is the amount of data.

Table 1. Normal distribution table

Service Level (%)	Service Factor
50	0.0
60	0.3
70	0.5
80	0.8
90	1.3
93	1.5
95	1.6
97	1.9
98	2.1
99	2.3
99.90	3.1

3.3. Reorder point

To Approaches through safety stock and reorder points are used to optimize costs in the supply chain so that vaccine supplies can be well controlled. Optimization of costs used in the supply chain can be used as a basis for calculating safe stocks and reorder points so that to determine a safe position in the inventory system, a safe stock placement is needed so that it can help or support decision making when ordering goods [15]. The point of reordering an item is an action that must be taken to replenish the inventory [23].

Several factors can affect the reorder point, lead time, level of usage per unit time and safety stock. To calculate the minimum amount for reorder, reorder point assumes that the demand during the waiting time and the waiting time itself is constant. So that the equation used to calculate the reorder point is as in Eq. 3,

$$ROP = (d \times L) + SS \tag{3}$$

where ROP is the reorder point, while d is the average demand then multiplied by L , namely the lead time or the time it takes from ordering to the goods until then added to the amount of safety stock.

3.4. Cost optimization

EOQ is the number of materials used or required at each purchase. In this study, the limit for the EOQ value was used as the maximum limit on vaccine storage. This is done considering the number of requests for vaccines is not too large.

To find out how much inventory will be ordered, use Eq. 4 as follows,

$$EOQ = \sqrt{\frac{2 \times F \times S}{C}} \tag{4}$$

by calculating FF , which is the cost of each message times the number of goods needed (S), then dividing the cost for storage C .

4. Results and Discussion

The data obtained at the pharmacy warehouse is then processed to obtain information. The waiting time required for a vaccine order is one. This is obtained from the time it takes to order the vaccine until the vaccine arrives one day because it is in the same city. The next step is to find the value of the safe stock, the average usage, the point of reordering, and after that, the calculation is done by comparing the costs incurred by the hospital without using the reorder point and with the reorder point approach.

4.1. Lead time

Data processing is used for data processing. The first step is to determine the lead time. When an order is made to the pharmacy warehouse, the lead time required is 1 day because the pharmaceutical supplier is located in the same city.

4.2. Safety stock

The calculation of the amount of safe inventory (Safety Stock) for pharmaceutical warehouses is to find the Z value (Service Level) which can be seen in Table 2 and σ LTD (standard deviation). The service level placed in the study is 95% meaning that the service level can be placed at 95% and out of stock at 5%. The 95% number is a commonly used probability distribution. The 95% determination is made because it is at this level because it is within two standard deviations (higher or lower) of the mean.

From the normal distribution table, the service level is placed at 95% so that the service level is located at 1.6. After getting the service level and service factor values, then we calculate the value of the standard deviation (σ) which is a measure of variation. The value of σ LTD is the standard deviation of weekly demand. To calculate the value of the standard deviation there are several steps such as preparing the demand data every week, then calculating the average demand, subtracting the average demand for each data, then squaring and summing all the squared results. So that the data is obtained as in Table 2 which is a calculation looking for the standard deviation for the Rotavirus vaccine. After seeing Table 2 about calculating the standard deviation for the Rotavirus vaccine, the standard deviation value is 2.42. In calculating the standard deviation of the Hexaxim Vaccine, some of the same steps are needed as used in the Rotavirus Vaccine, such as the weekly demand for Hexaxim Vaccine, then the same calculation is done, see Table 3.

Table 2. Calculation table finding standard deviation for Rotavirus

week	Order i x_i	Average demand (\bar{x})	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	0	3	-3	9
2	5	3	2	4
3	1	3	-2	4
4	5	3	2	4
5	4	3	1	1
6	2	3	-1	1
7	0	3	-3	9
8	5	3	2	4
9	3	3	0	0
10	4	3	1	1
:	:	:	:	:
19	1	3	-2	4

Table 3. Calculation of the standard deviation of the Hexaxim Vaccine

week	Order i x_i	Average demand (\bar{x})	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	0	3	-3	9
2	2	3	-1	1
3	3	3	0	0
4	0	3	-3	9
5	0	3	-3	9
6	6	3	3	9
7	5	3	2	4
8	0	3	-3	9
9	9	3	6	36
10	2	3	-1	1
:	:	:	:	:
19	0	3	-3	9

So that the value obtained after looking at Table 2 for the standard deviation of the Hexaxim Vaccine is 3.16. After the value for the service factor and standard deviation is obtained, the value of the safety stock for the Rotavirus vaccine is $1.6 \times 2.442 = 3.9072$ rounded to 4 and $1.6 \times 3.16 = 5.056$ for the Hexaxim vaccine safety stock.

4.3. Average weekly demand

The average demand for vaccines is to add up all the data on demand for vaccines, both Rotavirus and Hexaxim Vaccines. Consider Table 4.

Table 4. Weekly historical data demand for Rotavirus Vaccine and Hexaxim Vaccine

Week	Order	
	Hexaxim Vaccines	Rotavirus Vaccines
1	0	0
2	2	5
3	3	1
4	0	5
5	0	4
6	6	2
7	5	0
8	0	5
9	9	3
10	2	4
11	2	3
12	8	6
13	6	0
14	0	4
15	3	6
16	0	3
17	7	9
18	7	4
19	0	1
	$\Sigma = 60$	$\Sigma = 65$

From the data in Table 4, the calculation results for the average demand for Hexaxim Vaccine are 3.15 and 3.4 for the Rotavirus vaccine. This value is obtained from the number of each vaccine divided by the number of weeks. In this period it is 19 weeks.

4.4. Reorder point

Order control uses the Reorder Point approach, which is to determine the amount of inventory that will be reordered by looking at how much safety stock is. So to be able to find out how much the reorder point value obtained is 7 for the Hexaxim vaccine and 8 for the Rotavirus vaccine the figure is obtained by multiplying the average demand by the waiting time plus the safety stock. After determining the amount of inventory to reorder, then you can calculate how much the cost optimization will be by calculating the number of vaccine orders to be ordered.

4.5. Optimizing the cost of providing vaccines at the hospital

The application of the Economic Order Quantity is closely related to the lack of final stock in the inventory, by applying the Economic Order Quantity policy, how much vaccine orders will be obtained. This is of course closely related to the cost of the EOQ message so that it can overcome out of stock. By using the equation according to the costs used in Table 5. This table is the type of costs used for calculations, please look at Table 5. After calculating for cost optimization, the values obtained are 8 for the Hexaxim vaccine and 8 for the Rotavirus vaccine. Both values are obtained by performing calculations using Eq. 4.

Table 5. Estimated cost table for vaccines

Name	Cost
Ordering cost	IDR 1,500 / ordered IDR 19,500 / month
Holding cost	IDR 56,612 /month
Price Vaccines Rotavirus	IDR 450,000
Price Vaccines Hexaxim	IDR 950,000

4.6. Comparison of cost

The calculation of accuracy is done by comparing the results of calculations from the hospital with the research, so that the results obtained are as shown in Table 6 for the Hexaxim vaccine and Table 7 for the Rotavirus vaccine. Consider Table 6 and Table 7.

The result of this research is a case study with the results of calculations carried out at the hospital and in the study. The equation used is to use the equation in previous studies [15]. By calculating the information regarding the point of reordering, so that the pharmacy can be accessed when to reorder, so that when is the right time and how much to order will be able to optimize the cost of procuring vaccines. In Table 6 and Table 7 it can be seen the comparison between the pharmacy warehouse and research using reorder points.

Table 6. Comparison of cost table between hospital and Hexaxim vaccine research

Conclusion	Hospital	Research
Total number of vaccine orders	67	61
Vaccine Purchase Costs	IDR 63,650,000	IDR 57,950,000
Holding cost	IDR 210,000	IDR 283,060
Ordering cost	IDR 111,000	IDR 147,000
Total	IDR 63,971,000	IDR 58,380,060
Difference	IDR -	IDR 5,590,940

Table 7. Comparison of cost table between hospital and Rotavirus vaccine research

Conclusion	Hospital	Research
Total number of vaccine orders	70	62
Vaccine Purchase Costs	IDR 31,500,000	IDR 27,900,000
Vaccine storage costs	IDR 210,000	IDR 268,448
The cost of ordering the vaccine	IDR 91,500	IDR 106,500
Total	IDR 31,801,500	IDR 28,274,948
Difference	IDR -	IDR 3,526,552

5. Conclusion

In this study, the calculation was only obtained from the need for vaccines without damaged or expired vaccines. The results obtained using the reorder point approach and safety stock for the supply of Hexaxime vaccine and Rotavirus vaccine were IDR 5,590,940 and IDR 3,526,552, far less in the study than in the hospital. In future studies, it is expected that the calculation for the number of damaged and expired vaccines needs to be taken into account.

Author Contributions

Lenny Margaretta Huizen formulated the goals of research and developing software. Titis Handayani developed model design and data accuracy. Saifur Rohman Cholil validating research output, responsible for research activities. Yanti Faradilah reviewed and edited the total manuscript.

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Declaration of Competing Interest

We declare that we have no conflict of interests.

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