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Sensitivity Analysis of Average Inventory Level (AIL) at a Specialized Hospital

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Abstract. *Hospital inventory management play a very significant role in hospital's performance. Too much inventory wiil lead to excessive inventory cost but too low inventory might result in dissatisfactions of patiens and lack of performance of physicians or doctors. Economic order Quantity (EOQ) is an inventory control method that can help hospital to minimize total inventort cost. However, managers might find difficulties in deterimining the right amount of ordering and holding cost which are needed in calculating EOQ. This research is a case study from a class "A" specialized hospital. Inventory data of pharmaceutical items are calculated to measure the sensitivity of changes in ordering and holding cost to average inventory level which will lead to understock or overstock. Different ordering cost and holding cost will lead to different proportion of overstock and understock but will not give a significant differences. This research recommend EOQ model to be used in hospital inventory management inspite of the difficulty and hesitation of hospitals to estimate ordering and holding cost.*

Keywords: *Economic order quantity, sensitivity analysis, hospital inventory management, overstock, healthcare inventory management, holding cost, ordering cost, fixed order quantity*

Abstrak. *Manajemen persediaan rumah sakit memainkan peran yang sangat penting dalam kinerja rumah sakit. Terlalu banyak persediaan akan menyebabkan biaya persediaan meningkat, namun persediaan yang terlalu rendah juga bisa mengakibatkan ketidakpuasan pasien serta rendahnya kinerja pelayanan dokter kepada pasien. Economic Order Quantity (EOQ) adalah metode pengendalian persediaan yang dapat membantu rumah sakit untuk meminimalkan biaya persediaan total. Umumnya manajer menemukan kesulitan dalam menentukan biaya pemesanan dan biaya penyimpanan yang dibutuhkan dalam menghitung EOQ. Penelitian ini merupakan studi kasus dari rumah sakit khusus kelas A. Data inventaris barang farmasi dihitung untuk mengukur sensitivitas perubahan dalam pemesanan dan biaya penyimpanan terhadap tingkat persediaan rata-rata yang akan menyebabkan kondisi understock atau overstock. Biaya pemesanan dan biaya penyimpanan yang berbeda akan menghasilkan proporsi overstock dan understock yang berbeda namun tidak akan berbeda secara signifikan. Penelitian ini menyarankan penggunaan model EOQ untuk digunakan dalam manajemen persediaan rumah sakit walaupun terdapat kesulitan dan keenggaran dari rumah sakit untuk mengestimasi biaya pemesanan dan penyimpanan.*

Kata kunci: *Economic order quantity, analisis sensitivitas, manajemen inventori rumah sakit, overstock, manajemen persediaan di bidang kesehatan, biaya pemesanan, biaya penyimpanan, fixed order quantity*

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Introduction

Efficient inventory management is a crucial matter in an organization especially in pharmacy practice (Ali, 2011). Inventory is one of the most costly part of a business as well as one of the most expensive assets of many companies, which representing as much as 50% of total invested capital (Heizer & Render, 2014). Therefore, by reducing inventory cost, it will decrease the total of healthcare cost (Gebicki, Mooney, Chen, & Mazur, 2014). The primary goal of inventory management is to avoid holding too much inventories because holding too much or too little inventory will lead to business failure. Understocking can result in increased dissatisfaction of patients and can also result lack of performance of physicians or doctors (De Vries & Huijsman, 2011). While overstocking will result in increasing holding cost.

The objective of inventory control is to make inventory decisions that minimize total cost of inventory not to minimize total inventory (Schwarz, 2008). In the healthcare business especially in hospital or pharmacy, stock of healthcare product is related with saving lives, thus there is a perceived need to have high levels of service by keeping plenty of stock in their inventory (Beier, 1995). According to Uthayakumar and Priyan (2013), the high level of inventory will not only prevent healthcare product shortages that will give great impact on patient, but it will also prevent the financial losses. Thus, reducing inventory cost by decreasing the inventory level only is not appropriate, since the customers will complaint if the service level did not provide their need (Bowersox, Closs, & Cooper, 2002).

Therefore, to manage stock of healthcare product as well as ensuring there is a constant supply of drugs and medical product, a healthcare organization needs to apply appropriate inventory management methods (Roy, Manna, & Sarker, 2010).

Healthcare industries pay a little intention to management of inventories. Unlike, in sector manufacturing, planning and controlling inventory in healthcare industry still less developed (Hans, Van Houdenhoven, & Hulshof, 2012). Meanwhile there are several categories of inventories in a hospital, they are such as pharmaceutical items, medical equipment, and obsolence products.

According to Kelle, most hospitals use min-max par levels as inventory method for all inventory items. But the truth is hospital must use different method for different inventory category, and reviewed those methods regularly (Kelle, Woosley, & Schneider, 2012). M Bijvank and IFA Vis (2012) mentioned that most inventory management system at hospitals department are characterised by lost sales, periodic reviews with short lead times, and limited storage capacity.

But Uthayakumar and Priyan (2013) argued that periodic inventory review policies are not applicable in practical healthcare settings due to the uncertainty of patient arrivals and resulting demand. Periodic inventory review policies does not consider Cycle Service Level (CSL) which is critical in most hospitals. Uthayakumar and Priyan supported Woosley's research (2009) by saying although continuous review policy have some limitations in the context of healthcare supply systems, continuous review policy is more suitable than a periodic review approaach in healthcare inventory management. Those limitations according to Woosley and Uthayakumar and Priyan are the model only based on cost and do not consider restricted capacity.

Continuous Review Policy is known as Economic Order Quantity (EOQ). EOQ aim is to calculate economical quantity in every order to minimize total inventory cost (Schwarz, 2008). Costs associated with inventory of pharmacy product are carrying costs, shortage costs, and ordering costs (Hughes, 1984).

This research is investigating the inventory control methods in a specialized hospital in Bandung. A specialized hospital means that this hospital can provide treatment by specialists and subspecialists. Previous research in this hospital mentioned that using EOQ as inventory control method can help this hospital to save 56.93% from overstock of pharmacy items (Hafnika, Farmaciawaty, Adhiutama, & Basri, 2016). EOQ calculate optimal order quantity for each product. For obtaining the optimal order quantity, annual demand of a product, ordering cost per order, holding cost, and product's price are needed to be known first. Ordering cost includes costs of supplies, forms, order processing, purchasing, clerical support, and so on (Heizer & Render, 2014).

However, there's difficulty in calculating the exact amount of ordering cost per order per product because usually goods are ordered simultanously. For example when placing order via email, the amount of money spent in this activity are hard to be calculated. Another example, the cost of placing an order by phone cannot be calculated accurately and also this phone cost is usually for several items not for one item, while ordering cost in economic order quantity is for each product per order placed. It is also the same with calculating holding cost. Hodling cost usually consist of housing cost, material handling cost, labor cost, investment cost, and pilferage, scrap, and obsolescence cost. Many firms fail to include all the inventory holding cost. Consequently inventory holding costs are often understated (Heizer & Render, 2014). An overall inventory carrying cost of less than 15% is very unlikely, but this cost can exceed 40%, especially in high-tech and fashion industry (Render, 2014).

If there's difficulty in determining the right amount of ordering and holding cost, then there will be a big chance that there's missed calculated optimal order quantity. Many healthcare providers that we interviewed are hesitate to use EOQ method since they never calculate the cost of holding and ordering.

Total inventory cost is insensitive to order quantities, changes in order quantities have a relatively small impact on annual setup costs and inventory holding costs (Simchi-Levi, Simchi-Levi, & Kaminsky, 2008). If decision maker orders 20% more than optimal order quantity, the increase of total inventory cost will be no more than 1.6% (Simchi-Levi et al., 2008).

Previous research have use single inventory policy to increase patient safety while minimizing total cost. Gebicki mentioned that lots of improvements in medication supply in hospitals, including ordering drugs by online system could decrease ordering cost (Gebicki et al, 2014). In his research, Gebicki et al. use EOQ and other modified method to determine which system factors are important in choosing inventory policy. Since there's lots of improvements in how ordering and holding inventory, this research will show whether amount of ordering cost and holding cost have a significant affect on ordering policy.

Theory development of continuous review policy have been done very widely. Simchi Levy show the sensitivity of changing ordering cost towards total cost. There's many previous research that evaluate and propose suitable models for inventory management in healthcare industry. But most of those research haven't show the sensitivity of changing amount of ordering cost and holding cost to Average Inventory Level (AIL). In other industries research on continuous review policy have develop widely and also used in many companies. But on healthcare industry, most of those players are hesitate to use continuous review policy. Our preliminary Focus Group Discussion with healthcare representatives in Bandung, show that they are hesitate to use continuous review policy because they never estimate the cost of ordering and holding inventory.

This research will measure the affect of ordering and holding cost changes to the changes of AIL. AIL is amount of inventory that was carried from time to time which affected by number of optimal order quantity and safety stock carried. If calculated AIL is higher than actual AIL that means there's understock mean while if calculated AIL is lower than actual AIL that means there's overstock. Since there are several categories of inventory in healthcare industry, this Research will focus on calculating AIL on pharmaceutical items. Kelle mentioned that pharmaceutical items represent a great percentage of costs in healthcare industry due to the significant cost of these products and their storage and controls (Kelle et al., 2012). This research will focus in calculating the sensitivity of changing ordering and holding cost to AIL for pharmaceutical items in a specialized hospital in Bandung.

Research Methodology

This research is using mixed method to analyze the data. Qualitative method is used to gain understanding of the problem and to develop ideas to solve the problem. Pharmacy and medical equipment inventory data was collected from January 2015 until May 2016. The data contains information of 1.164 drugs. Quantitative method is used to calculate hospital's Economic Order Quantity (EOQ) and Average Inventory Level (AIL). EOQ calculate Q* which represent number of units per order while when to order is represent in Reorder Point (ROP).

$$Q^* = \sqrt{\frac{2x\ Annual\ Demand\ x\ Ordering\ Cost}{Holding\ cost}}$$

This research use probabilistic assumption, where demand is considered as variable.

$$safety\ stock\ (ss) = \sigma_D \sqrt{L}$$

Most of healthcare facility use reorder point as daily demand times lead time, this research considered safety stock as a buffer of ROP.

$$ROP = dL + ss$$

While in calculating both actual and calculated AIL, this research use this equation:

$$AIL = \frac{Q^*}{2} + ss$$

Results and Discussion

Hanifka's research on this class "A" hospital (Hafnika et al., 2016) has determined several assumption that was used in the calculation. They are:

Ordering cost: Rp 5.000,-
Holding cost: 5%
Lead time: 45 days
Customer service level: 95%

Lead time 45 days are used because this research investigate pharmaceutical items that was funded by Badan Layanan Umum (BLU) and these items are ordered using E-catalog which take 30-45 days lead time. Render determine inventory holding cost equal to 26% (housing cost 6%, material handling cost 3%, labor cost 3%, investment cost 11%, pilferage, scrap, and obsolescence costs 3%) (Render, 2014). This research will use Hanifka's assumption except for holding cost. We use Hafnika assumption since the data used in this research is the same. Holding cost 26% will be used as base in comparing sensitivity analysis of the changing of holding and ordering cost.

Using assumption mentioned above, the sensitivity of changes in ordering and holding cost to Average Inventory Level can be calculated. From 1455 types of drugs there are 926 items (64%) that has actual condition 0 while the calculated AIL was also 0, this means there' no demand and no stock. This items are classified as discontinued item. With holding cost 26%, Economic. Order Quantity will make this hospital save 57% inventory cost from overstock of pharmaceutical items. This only differ 0,07% from Hanifa's research which used 5% holding cost.

Table 1.
Percentage Gap Between AIL Theory and Actual

Inventory Status	AIL Theory	AIL Actual	% Gap
DeadStock		IDR 205.380.960	
Overstock	IDR 783.266.479	IDR 1.821.736.226	-57%
UnderStock	IDR 643.804.628	IDR 300.129.154	+115%
Total	IDR 1.427.071.107	IDR 2.327.246.339	-63%

Souce: data calculation

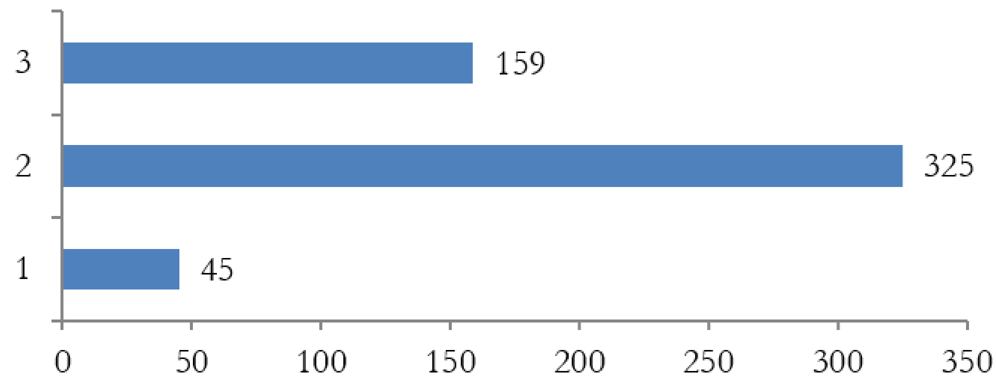

Figure 1.
Inventory Status Using IDR 5.000 Ordering Cost and 26% Holding Cost.

As shown in Table 1, the cost of understock items will increase 115% but the overall cost of understock and overstock will decrease 63%. As shown in Figure 1, using ordering cost Rp 5000 per order and holding cost 26%, there are 325 (61,4%) overstock items, 159 (30,1%) understock items, and 45 (8,5%) deadstock items. Overstock means calculated AIL is lower than actual AIL which will lead to high holding cost. The high number of overstock show that this hospital has excess number of inventory which also high amount of money are spent in form of goods.

Understock means that calculated AIL is higher than actual AIL, so there's possibility of loss sale of stockout. In a hospital, stokout will result in dissatisfaction of patients and can also result in lack of performance of doctors. Table 2 shows items with largest gap in between actual AIL and calculated AIL.

Items with positive gap are categorized as overstock, because their actual AIL higher than calculated AIL. Stelaris Combines Posteriror Vitrec is item with highest positive gap. Using EOQ will help hospital to save IDR 116.121.457 for this item. Meanwhile items with negative gap are categorized as understock.

For example, Oxan HD is item with largest negative gap in this hospital. This means that the calculated AIL is higher than the actual AIL which lead to posibility of understock. According to EOQ calculation, this hospital should increase inventory for Oxan HD to prevent understock. With current policy Oxan HD will have IDR 73.133.664 loss sale. This is the largest understock for pharmaceutical items in this hospital.

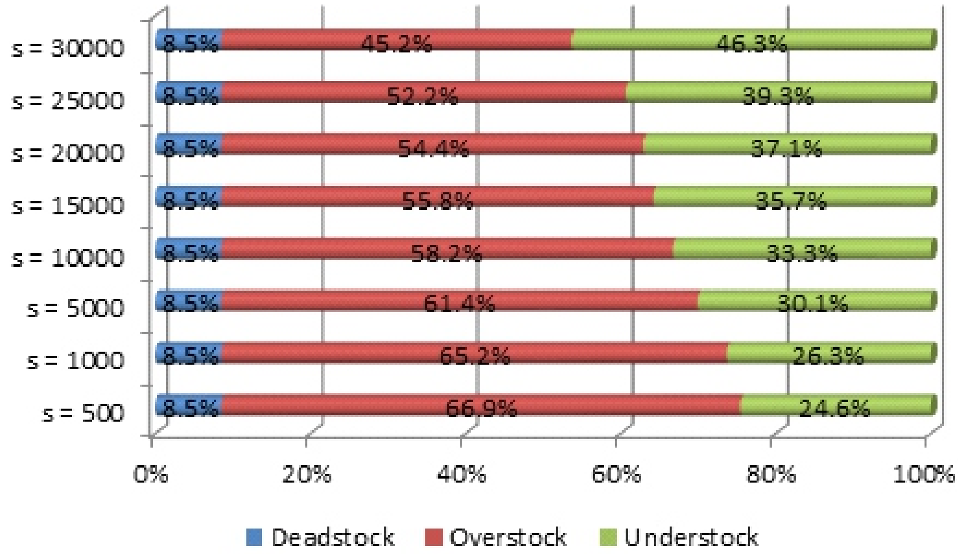

Figure 2.
Percentage of Inventory Status With Different Ordering Cost.

Table 2.
Items with Highest Gap Between Calculated AIL and Actual AIL

Item Name	AIL Theory	AIL Actual	Gap	Category
STELARIS COMBINES POSTERIOR VITREC (BLU)	239.412.293	355.533.750	116.121.457	Overstock
AVASTIN INJEKSI (BLU)	25.107.217	62.730.631	37.623.414	Overstock
BLADES No. 15 (BLU)	880.669	36.906.300	36.025.631	Overstock
LUCENTIS (BLU)	19.962.295	52.806.572	32.844.277	Overstock
CAPTOPRIL 12,5 MG (ASKES)	65.339	4.980	-60.358	Understock
CRESENT OASIS (BLU)	3.867.065	60.759	-3.806.306	Understock
JARUM HIDRODISECTION (BLU)	4.578.232	264.000	-4.314.232	Understock
OXAN HD (BLU)	73.896.789	763.125	-73.133.664	Understock

Source: data calculation

Figure 2 show percentage of overstock and understock using altered ordering cost. As the ordering cost increase, number of overstock items will decline while understock items will increase. This is because the increase of ordering cost will lead to increased optimal order quantity. The increased of optimal order quantity will lead to increased calculated AIL and this will make the gap between calculated and actual AIL closser. 100% increase in ordering cost (from IDR 5.000 to IDR 10.000) decrease number of overstock to 45,2% and increase number of understock to 46,3%. The average changes in number of overstock and understok for every 100% changes in ordering cost is 4.4%.

Items that previously were overstock might be no longer overstock even might become understock. For example, using ordering cost IDR 5.000 BIO ATP TABLET (BLU) was categorized as overstock with gap between actual and calculated AIL 7.953 but when ordering cost are changed into IDR 10.000, the gap are changed into -10.990 which make BIO ATP TABLET (BLU) categorized as understock items. The same thing happened to 17 items when ordering cost change to IDR 10.000. This happens because ordering quantity increase which make calculated AIL also increase and make gap between calculated and actual AIL also increasing. Table 3 shows items that are moved to understock items if ordering cost increased to IDR 10.000. Before, they are categorized as overstock items.

Table 3.
Items That Moved to Understock Items if There's 100% Increase in Ordering Cost

Items Name	Ordering cost IDR 5.000		Ordering cost IDR 10.000	
	Category	Gap	Category	Gap
BIO ATP TABLET (BLU)	Overstock	7.953	Understock	(10.990)
BUFFECT SYIRUP (BLU)	Overstock	7.402	Understock	(45.433)
CORDARONE INJEKSI (BLU)	Overstock	10.740	Understock	(15.884)
HISTRINE SIRUP (BLU)	Overstock	39.189	Understock	(6.783)
LAPIBAL 250 (BLU)	Overstock	26.652	Understock	(31.028)
MIDAZOLAM INJEKSI (BLU)	Overstock	20.165	Understock	(8.738)
MYLANTA TAB (BLU)	Overstock	7.961	Understock	(6.533)
NEW DIATABS TABLET (BLU)	Overstock	2.112	Understock	(11.409)
PANTOCAIN 2% 15ML ED (BLU)	Overstock	105.231	Understock	(19.437)
POLYDEX ED (BLU)	Overstock	72.401	Understock	(64.662)
PROFENID SUPP (BLU)	Overstock	20.422	Understock	(38.491)
PRONALGES SUPP (BLU)	Overstock	34.409	Understock	(6.233)
RIFAMPICIN 450MG (BLU)	Overstock	5.505	Understock	(828)
SILICON TUBING (BLU)	Overstock	9.851	Understock	(81.139)
SOCLAF (BLU)	Overstock	50.748	Understock	(64.864)
SPATEL KACA	Overstock	10.997	Understock	(7.256)
THROMBHOPOB GEL (BLU)	Overstock	1.279	Understock	(17.398)

Source: data calculation

Using the beginning assumption, holding cost was altered to see the sensitivity changes of number of overstock and understock item for pharmaceutical items. If holding cost was increased, number off overstock will increase as understock will decrease. This is because as holding cost increase, number of optimal order quantity will decrease, so calculated AIL will also decrease. When actual AIL are still the same, the gap between actual and calculated AIL will increase so number of overstock will also increase. The effect of changing holding cost to percentage of overstock and understock can be seen in table 4 bellow. 300% changing of holding cost (from 5% to 15%) will affect to 7% increase of overstock and 7% decrease on understock.

This research use 26% holding cost as assumption, differ with previous research that used 5% holding cost. The differences is only 9,4% in number of understock and overstock. Calculation using 1% (2500% decrease from assumed holding cost) holding cost show overstock and understock changed as much as 25%. There are several items that previously were categorized as understock that now were categorized as overstock due to the decrease of optimal order quantity.

Table 4.
Comparison Between Inventory Status with Different Holding Cost

Inventory Status	h = 1%	h = 5%	h = 15%	h = 26%
Dead stock	8,5%	8,5%	8,5%	8,5%
Over stock	36,1%	52,0%	59,0%	61,4%
Under stock	55,4%	39,5%	32,5%	30,1%

Souce: data calculation

Conclusion

Changes in ordering cost will lead to changing inventory level which will increase or decrease gap between actual and calculated AIL, depend on the increase or decrease of ordering cost. However, the increase or decrease of 100% ordering cost will only affect 2-4% changes in inventory status. As the ordering cost increase, number of overstock items will decline while understock items will increase. This is because the increase of ordering cost will lead to increased optimal order quantity. The increased of optimal order quantity will lead to increased calculated AIL and this will make the gap between calculated and actual AIL closser. 100% increase in ordering cost (example: from IDR 5.000 to IDR 10.000) will decrease number of overstock to 45,2% and increase number of understock to 46,3%. The average changes in number of overstock and understok for every 100% changes in ordering cost is 4.4%.

Items that previously were overstock might be no longer overstock even might become understock. Meanwhile the changes in holding cost also will lead to changing inventory level but will not significantly affect the percentage of invetory status. 100% changes of holding cost will only lead to 7% changes in number of overstock and understock. 2500% increase of holding cost (from 1% to 26%) will lead to 25% changes in number of overstock and understock. This research show that missed prediction of ordering and holding cost assumption in economic order quantity will not affect inventory status significantly. That's why hospitals should not hesitate to use EOQ as inventory method. Of course this method should be compared with other hybrid method based on the hospital's condition and inventory policy. By using EOQ, hospital also can calculate their customer service level (CSL) and make action plan to increase their CSL. This should be supported by future research that calculate CSL.

However this research is case study to a class "A" specialized hospital, therefore future research must be done in order to generalize this research's outputs by including the entire class of inventory as well as adding several other type of hospitals.

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