

Developing Inventory Management Policy for Drugs with Medium and Low Consumption Value in Hospital

นิพนธ์ต้นฉบับ

Original Article

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บทคัดย่อ

วัตถุประสงค์: ยาเป็นทรัพยากรสำคัญในโรงพยาบาล จึงต้องมีการบริหารจัดการให้มีเพียงพอต่อการรักษาผู้ป่วย งานวิจัยนี้มีวัตถุประสงค์เพื่อกำหนดนโยบายที่เหมาะสมในการจัดการสินค้าคงคลังยาที่มีมูลค่าปานกลางและมูลค่าน้อย **วิธีการศึกษา:** การวิเคราะห์โดยอาศัยข้อมูลการใช้ยาจริงในอดีตของโรงพยาบาลรัฐกรณีศึกษา และเปรียบเทียบนโยบาย Min/Max ที่โรงพยาบาลใช้ในปัจจุบันกับนโยบายที่ได้จากการทบทวนวรรณกรรม จากงานวิจัยที่ผ่านมาได้มีการศึกษานโยบายการจัดการสินค้าคงคลังที่เหมาะสมของกลุ่มยาในโรงพยาบาลที่มีมูลค่าสูง (ยากลุ่ม A) ไปแล้ว การศึกษานี้มุ่งที่ กลุ่มยาที่มีมูลค่าปานกลาง (ยากลุ่ม B) และกลุ่มยาที่มีมูลค่าน้อย (ยากลุ่ม C) **ผลการศึกษา:** สำหรับยาที่มีมูลค่าปานกลางและมูลค่าน้อย นโยบาย Min/Max ไม่เหมาะสมเมื่อเทียบกับนโยบายอื่นที่พบในวรรณกรรม โดยนโยบาย Min/Max ซึ่งพิจารณาเพียงปัจจัยด้านปริมาณความต้องการเพียงปัจจัยเดียวโดยไม่สนใจความสำคัญด้านการรักษาจะไม่เหมาะสมเนื่องจากอาจทำให้เกิดการขาดแคลนและเกิดการเก็บสินค้าขึ้นได้ **สรุป:** พบว่าการกำหนดนโยบายการจัดการสินค้าคงคลังในโรงพยาบาลนั้น ควรจะต้องคำนึงปัจจัยทางด้านความต้องการและความสำคัญในการรักษาไปพร้อมกัน

คำสำคัญ: การจัดการสินค้าคงคลัง, โรงพยาบาล, ยา

Abstract

Objective: Drugs are the important resource of the hospital. The hospital keeps stock and manages drug inventory in order to ensure adequate on-hand inventory for patients. This study aimed to determine inventory policy suitable for drugs with medium and low consumption value. **Methods:** This study used historical drug demand data of a large government hospital to test the existing Min/Max inventory policy against other policies found in the literature. Since policy suitable for drugs with high consumption value (group A) was known, we focused on drugs with medium (group B) and low (group C) consumption value. **Results:** For groups B and C, the Min/Max inventory policy was not suitable compared with the others from the literature. This was because it took only the consumption value, not the drugs' clinical importance, into account. The sole Min/Max policy could potentially cause shortage and overstock. **Conclusion:** To apply a proper inventory management policy for drugs in the hospital, clinical factors, in addition to consumption value, should be taken into consideration.

Keywords: inventory management, hospital, drugs

Introduction

In Thailand, drug expenditure has been increasing from 36,506 million Baht in 2000 to 98,375 million Baht in 2008. With an average increase rate of 15% per year, the drug expenditure continues to rise. It has been estimated that 46.7% of the healthcare expenditure is the drug costs which is as twice as that if the developed countries.¹ It is obvious that almost half of the healthcare expenditure in Thailand is the cost of drugs.

To have an uninterrupted healthcare service, hospitals usually have the safety stock, or the minimum inventory level. To accurately estimate such safety stock, the monthly amount of drugs use from each of the hospital's departments is accumulated. This monthly drug usage volume is called the Monthly Sale or Msale. It has been accepted that once the drug inventory on hand is lower than 70 – 80% of the Msale, the pharmacist responsible for the central drug

distribution center should be prompted to place the order. The purchase volume should increase the inventory level to 100 – 150% of Msale. This type of practice is known as the Min/Max policy which has been widely applied to all drugs items in the hospital. However, since most drug items have different demand characters, such universal use of Min/Max policy could be problematic.

Our previous study investigated drug inventory policies suitable for different types of drug regarding the usage volume. Drugs with a usage volume of 70% of the total annual drug expenditure (group A) were selected for analysis. The history data of drug usage in the fiscal year 2012 were tested against the Min/Max policy and other policies. It was found that the single Min/Max inventory management policy was not appropriate for all drug items especially those classified as vital drugs, which in part are

those for unusual urgent medical needs such as anti-venom serums. With the unpredictable demand of these vital drugs, a universal Min/Max policy could easily lead to an inventory shortage. This kind of problem is devastating since these vital drugs need to be readily available at all times as the life-saving items.²

To further our investigation on the issue, we conducted this present study to determine the appropriate policy beyond group A drugs, including those with medium and low usage volume, i.e., groups B and C, respectively. In this study we defined groups B and C drugs as those with 15% and 5% of the total annual usage value. As a retrospective study, we used a set of historical data from the out-patient department (OPD) of a government hospital in the fiscal years of 2008 – 2010 to compare the present Min/Max inventory policy with other policies guided by the literature.

Methods

Recent inventory management policies of the hospital and general industrial goods were reviewed from the literature. System analysis in this present study was the modified method from our previous investigation on the drug inventory management system.² Historical demand data of the drug usage in the fiscal years of 2008 – 2010 were retrieved from the study hospital information system and categorized the total annual consumption value of each drug according to the ABC analysis.³ Only those drugs with the 15% and 5% of the total annual drug consumption values, or groups B and C, respectively, were selected for the analysis.

Of these select groups B and C drugs, based on the additional information provided by the hospital, we further classified clinical importance of the items according to the VEN classification.^{4,5} Once the ABC and VEN classification systems were applied simultaneously, six groups of drugs were classified, specifically drugs with medium usage and vital clinical importance (BV), drugs with medium usage and essential clinical importance (BE), drugs with medium usage and non-essential clinical importance (BN), drugs with low usage and vital clinical importance (CV), drugs with low usage and essential clinical importance (CE), drugs with low usage and non-essential clinical importance (CN).

After the ABC/VEN classification, we used statistical analysis to classify drug items based on the demand

characters which consisted of the distribution and the presence of the demand, in other words, the trend demand.³ These statistical methods included, but not limited to Run Test, Kolmogorov–Smirnov Test and Peterson–Silver Rule. We then test each inventory management policy using the Min/Max policy as the base case since it has been widely used in the hospitals in Thailand. Once all policies were compared, policies with the highest indices were determined.

1) Literature review

Inventory management aims at minimizing the inventory cost, and at the same time maintaining the desirable service level to the customers. However, since the inventory of the hospitals contains medications in various forms as well as non-pharmaceutical medical products. These various products also have various costs. To better manage the inventory, one must prioritize the products by their costs. Otherwise, to micromanage every item of the products could be too costly and time-consuming.

1.1) The prioritization of the drug inventory based on inventory cost and clinical importance

To prioritize drug items in the hospital inventory based on their cost and clinical importance, the ABC Analysis and the VEN Classification have been recommended. The ABC Analysis, or the 20 - 80 Rules or Pareto Analysis³, has been widely used in classifying the inventory with various kinds of products. Based on ABC Analysis, products are classified into three groups. First, group A is the products accounting for 70% of the total inventory value and only 20% of the number of the inventory items. Group B products are those accounting for 15% of the total inventory value and about 30% of the inventory item numbers. Last, products in group C account for 5% of the total inventory value and as high as 50% of the inventory item numbers. For the medical products in Thailand, service levels have been reported to be 98:95:90 for groups A, B and C, respectively.⁴

In addition to the monetary value and item quantity, medical products possess the attribute of **clinical importance** that needs to prioritize in their inventory management. The VEN classification reflects the medical necessity and urgency aspect of each of the products.⁵ Based on the VEN classification, three classes include class V (Vital), class E (Essential), and class N (non-essential).

Class V refers to those drugs for life-saving or highly emergent medical conditions. They need to be readily available at all time. Drugs in class E are needed in general medical conditions; while those in class N are those for the least critical conditions and that can be substituted by other drugs. In each hospital, individual drug items in each of the there VEN classes can be revised annually.

To better manage the inventory of the hospital, the simultaneous application of the ABC and VEN classifications has been widely recommended. The method takes the annual consumption value and the clinical importance of the drug products into account simultaneously, by the ABC and VEN systems, respectively.

1.2) ABC/VEN classification system

Based on this **ABC/VEN system**, nine groups are classified. These include those with high consumption value and high clinical importance (1-AV), high consumption value and moderate clinical importance (2-AE), high consumption value and low clinical importance (3-AN), medium consumption value and high clinical importance (4-BV), medium consumption value and clinical importance (5-BE), medium consumption value and low clinical importance (6-BN), low consumption value and high clinical importance (7-CV), low consumption value and moderate clinical importance (8-CE), low consumption value and clinical importance (9-CN). In our present study, we studied only those with medium and low consumption values, i.e., groups 4 to 9.

1.3) Inventory management policy

In terms of stock replenishing, the **inventory management policy** helps identify when to place and order, and how much to order to minimize the total inventory cost per time per unit. Two kinds of policy have been used.^{3,6} In the first system, the **(s, Q) inventory policy** or the **two-bin system**, one would place an order when the inventory reaches the re-order point (s), with an order quantity (Q). This approach is an application of the economic order quantity (EOQ). This (s, Q) system has been widely used and is effective in controlling the inventory quantity and minimizing the inventory cost.

Like the (s, Q) inventory policy, the **(s, S) inventory policy** indicates that one should place an order when the inventory reaches the re-order point (s). However, the (s, S) inventory policy suggests that the order quantity should be the one make the inventory reach the maximum inventory level (S). It has been found this (s, S) inventory policy has been widely with all drug items in all hospitals' inventory system.

It is thus concluded that the inventory policy, both (s, Q) and (s, S), suggests a continuous monitoring of the inventory level. Once the inventory level drops and reaches a the re-order point (s), the order must be place in a timely fashion, either with an economic order quantity by the (s, Q) policy, or an the quantity that helps reach the maximum inventory level by the (s, S) policy.

In addition to those factors described above, the use of (s, Q) or (s, S) policy depends also on other inventory characteristics. For example, whether the product demand is static or variable could determine the policy. Many inventory management policies have been developed to be specific for various demand characters as follows.

First the policy that uses mean and standard deviation of the inventory consumption is specific to drugs with static and random demand, in other words, no trend of the demand.^{2,7-11} The policy that uses probability to determine re-order point (ROP) and order quantity is more specific to drugs with lumpy and random demand (i.e., no trend), and drugs that their consumption values have non-normal distribution.^{7,8} The policy that uses probability and regression analysis to determine ROP and order quantity is specific to drugs with lumpy and trend demand.^{7,8}

With various inventory policies mentioned above, four inventory management policies specific to various drugs' consumption could be found. First, it is the policy drugs with normal distribution of the demands where their demands are uniformly distributed and no trend of the demand is found. Second, it is the policy for drugs with normal demand distribution with no trend but lumpy demand(s) at some times. Third, it is the policy for drugs with normal distribution and a trend in demand. Last, it is the policy for drugs with non-normal distribution of the demand. These policies with their corresponding mathematic models for calculating re-order point and order quantity are shown in Table 1.

Table 1 Inventory policy from previous studies for particular demand characteristics.

Number	Demand character	Inventory policy
1	Normal distribution with no trend but static demand	(s,S) policy for normal distribution demand ^{3,6} $s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL} \cdot \sigma_{week}}{n}$ $S = M \frac{\mu_{week}}{n} + k + s$
		(s,Q) policy for static demand and pack size ordering ^{3,6} $s = \mu_{day}(L+1)$ $Q = \max \left\{ \left\lceil \frac{\mu_{day}n + S - I}{y} \right\rceil, mo \right\}$
		(s,Q) policy based on EOQ ^{3,6} $s = \mu_{day} \times L$ $Q = \sqrt{\frac{2AD}{h}}$
2	Normal distribution with no trend but lumpy demand	(s,Q) policy for normal distribution demand with lumpy demand and pack size ordering ^{7,8} $s = \frac{L \cdot \mu_{week} + z \cdot \sqrt{nL} \cdot \sigma_{week}}{n}$ $Q = \max \left\{ \left\lceil \frac{\mu_{day}n + S - I}{y} \right\rceil, mo \right\}$
		Fixed Period Demand ³ $s =$ order every month (Fixed ordering time) $Q =$ average weekly demand
		Silver Meal ³ The amount to order is determined to achieve the minimum inventory cost.
3	Normal distribution with trend demand	(s,Q) based on a trend demand ^{7,8} $s = \int_{t=c}^{t=d} f(d_t) dt + z \sqrt{L \sigma_{day}}$ $Q = \int_{t=a}^{t=b} f(d_t) dt + k$
4	Non-normal distribution	Fixed Period Demand ³ $s =$ order every month (Fixed ordering time) $Q =$ average weekly demand
		Silver Meal ³ The amount to order is determined to achieve the lowest inventory cost.

Note:

- s = re-order point (unit)
- L = lead time (day), and it was pre-determined at 14 days¹²
- μ_{week} = weekly mean of demands (unit)
- z = the standardized random variable (Z-score) which was determined by the service level based on the VEN groups
- n = service days in a week (day)
- σ_{week} = standard deviation of the weekly usage (unit)
- S = maximum inventory level (unit)
- M = storage day (day)
- k = special demand that was known before (unit)
- Q = order quantity (pack)
- μ_{day} = daily mean of demand (unit)
- I = inventory level at re-order point (unit); $I \leq s$
- y = the unit of boxes (unit)
- mo = minimum order quantity, which was pre-determined at zero⁷
- A = ordering cost (Baht/order); pre-determined as 5.775 Baht/order¹²
- D = weekly demand (unit)
- h = annual inventory unit cost (Baht/unit/year), equal to inventory cost (% per year) x good cost (Baht/unit); inventory cost was pre-determined at 20.5% per year¹²
- d_t = predicted usage demand at week t; with the presence of trend, t = the week order starting from December 2011 (t = 0, 1, 2, ...)

2) Data analysis and the results

Input data

Historical data of drug usage in the fiscal years of 2008 – 2010 of a university hospital with 1,300 beds were retrieved for analysis. Based on the ABC/VEN analysis, drugs were

classified into nine groups, specifically, AV, AE, AN, BV, BE, BN, CV, CE and CN. In this study, we studied only drugs with medium and low usage value (groups B and C, respectively) which comprised 1,743 drug items. Usage data

of these drugs were analyzed to fit the possible four types of demand characters from the literature previously described.

To examine the demand characters of the usage data of the study drugs, we used Box Plot test to determine and eliminate extreme data values, Kolmogorov-Smirnov test to determine normal distribution of the data, Run test to examine randomness of the data, regress analysis to determine a linear trend of the data, and Peterson-Silver rule to examine uniform and lumpy distribution (Figure 1).

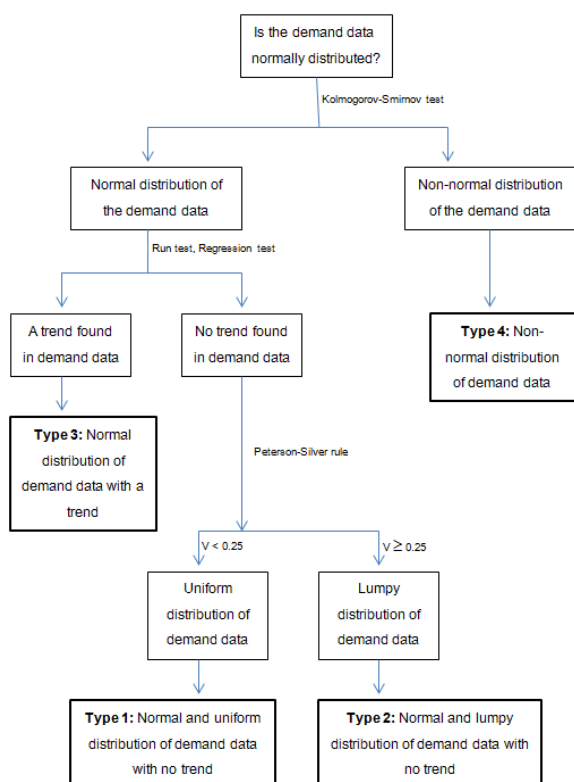


Figure 1 Schematic diagram of the statistical analysis on the type of demand characters of the usage data of the study drugs.

The demand characters of the six study drug groups

Based on the analysis results, **the demand characters of the six study drug groups** (BV, BE, BN, CV, CE, and CN) were as follows. First, drugs with medium consumption value and high clinical importance (BV) had three demand characters. These characters included 1) normal distribution with no trend, and a uniform demand distribution, 2) normal distribution with no trend, and a lumpy demand distribution,

and 3) non-normal distribution. Service level of this group of drugs was set at 95%.⁴

Second, drugs with medium consumption value and clinical importance (BE) also had three demand characters. These characters consisted of 1) normal distribution with no trend and a uniform demand distribution, 2) normal distribution with no trend, and a lumpy demand distribution, and 3) non-normal distribution. Service level of this group of drugs was set at 94%.

Third, drugs with medium consumption value and low clinical importance (BN) had two demand characters. These characters consisted of 1) normal distribution with no trend and a uniform demand distribution, and 2) non-normal distribution. Service level of this group of drugs was set at 93%.

Fourth, drugs with low consumption value and high clinical importance (CV) had three demand characters. These characters consisted of 1) normal distribution with no trend and a uniform demand distribution, 2) normal distribution with no trend, and a lumpy demand distribution, and 3) non-normal distribution. Service level of this group of drugs was set at 90%.

Fifth, drugs with low consumption value and medium clinical importance (CE) had four demand characters. These characters consisted of 1) normal distribution with no trend and a uniform demand distribution, 2) normal distribution with no trend, and a lumpy demand distribution, 3) normal distribution with a trend, and 4) non-normal distribution. Service level of this group of drugs was set at 89%.

Sixth, drugs with low consumption value and high clinical importance (CN) had three demand characters. These characters consisted of 1) normal distribution with no trend and a uniform demand distribution, 2) normal distribution with no trend, and a lumpy demand distribution, and 3) non-normal distribution. Service level of this group of drugs was set at 88%. From the findings mentioned above, we examined the inventory policy suitable for individual demand characters

The historical data of drug usage were tested against the existing Min/Max policy and other policies from the literature. The results of **the potential suitable inventory policies** are shown in Table 2.

Table 2 Potential suitable inventory policies for each type of demand characteristic of drugs with low and medium consumption value.

	Type of demand character			
	1) normal distribution with no trend, and a uniform distribution	2) normal distribution with no trend and a lumpy distribution	3) normal distribution with a trend	4) non-normal distribution
Potential policy for application	Min/Max	Min/Max	Min/Max	Min/Max
	(s,S) policy for normal distribution of the demand	(s,S) policy for normal distribution of the demand	(s,Q) policy for the demand with a trend	Fixed Period Demand
	(s,Q) policy for a uniform distribution of the demand and pack size ordering	(s,Q) policy for lumpy demand distribution and pack size ordering	-	Silver Meal
	(s,Q) policy based on EOQ	Fixed Period Demand	-	-
	-	Silver Meal	-	-
	Drug groups	BV, BE, BN, CV, CN	BV, BE, CV, CN	CE

3) The measures of the drug inventory performance

Once the type of the demand characteristics and the potential suitable inventory policies for each type of those demand characters were determined, the next step was to determine which factor or a combination of factors could potentially best judge the performance of the inventory management policy. This step was also crucial since not only the inventory consumption value, but also the clinical importance nature of the drug products were of great concern. We used a key performance index (KPI) based on

1) number of shortages, 2) number of days of shortage, 3) average inventory level, 4) inventory turnover, and 5) inventory-to-sale ratio.^{7,12}

To properly account for the consumption value and the clinical importance of each group of drugs in deciding the best indicators, the pairwise ranking technique was used. We asked three experts in healthcare logistics to prioritize the KPIs for these drugs with medium and low consumption values. The results of the KPIs suitable for judging the performance of the inventory policy of each of the two groups of drugs are shown in Table 3.

Table 3 Key performance index suitable for judging the inventory policy performance of drugs with medium and low consumption values by pairwise ranking technique.*

Drugs with medium consumption value (group B)	Drugs with low consumption value (group C)
BV: number of days of shortage	CV: number of days of shortage
BE: number of shortages	CE: average inventory level
BN: inventory-to-sale ratio	CN: inventory-to-sale ratio

* each final decision was made by at least two experts.

Table 4 Inventory policy suitable for each group of drugs and each type of demand characters, and the results of applying these suitable KPIs.

		Policies suitable for each group of drugs and each type of demand characters																	
		BV: medium consumption value and high clinical importance			BE: medium consumption value and clinical importance			BN: medium consumption value and low clinical importance			CV: low consumption value and high clinical importance			CE: low consumption value and medium clinical importance			CN: low consumption value and low clinical importance		
		1	2	4	1	2	4	1	4	1	2	4	1	2	3	4	1	2	4
Suitable policy	Min/Max	✓			✓						✓	✓							
	(s,S) policy for normal distribution of the demand																	✓	
	(s,Q) policy for uniform distribution of the demand and pack size ordering										✓							✓	
	(s,Q) policy for lumpy demand distribution and pack size ordering		✓			✓		✓			✓								
	(s,Q) policy for the demand with a trend													✓					
	Fixed Period Demand								✓					✓		✓		✓	
	Silver Meal			✓			✓												
		The results of applying suitable KPI to each group of drugs and each type of demand characters																	
		Days of shortage (days)			Number of shortage (units)			Inventory-to-sale ratio		Days of shortage (days)			Average inventory level			Inventory-to-sale ratio			
Application results	Before application	7	18	15	752	965	192	0.05	0.05	5	11	14	4,570	1,047	6,395	14	0.05	0.05	0.05
	After application	#	4	13	#	475	52	0.06	0.14	#	2	#	3,765	42	5,626	6	0.06	0.07	0.09

the results based on the prior inventory policy.

Results

After the historical data of drug consumption values were tested against the inventory policies including the present Min/Max policy as well as those from the literature (Table 2), we further tested for each KPI best judging each policy in each groups of drugs. The results are shown in Table 4.

Discussions and Conclusion

Our study tested the suitable inventory management policy applied to drugs with various demand characters on the actual historical data. We found that most demand characters were with non-normal distribution. This suggested the usage of the drugs with medium and low consumption value (groups B and C) was usually non-uniform and unpredictable. Usually drugs with this type of demand character should be managed by the Fixed Period Demand policy where the Fixed Interval of ordering should be applied. Safety stock and re-order point are calculated based on average demand or maximum demand. The order quantity was varied upon the latest demand.

For drugs with normal distribution of their usage with no trend and a uniform demand, Min/Max policy was found suitable. The (s,Q) policy for uniform distribution of the demand and pack size ordering was more appropriate if to reduce the product shortages. For drugs with normal but lumpy distribution of the demand with no trend, (s,Q) policy for normal demand distribution and pack size ordering could also be applicable. Based on these findings, the Min/Max policy did not serve well for a large number of drugs items in the hospital. It was mostly suitable for drugs with medium consumption value (group B) with normal and uniform distribution of the usage. For drugs with a low consumption value (group C), Min/Max policy was unsuitable for most of them except for those with low consumption value and vital clinical importance (group CV).

In terms of days of shortage, if the recommended policy was applied to group BV drugs with the demand character type 1 (normal distribution with no trend, and a uniform distribution), a similar seven-day of shortage was found when compared with the existing Min/Max policy. For group BV drugs with a type 2 demand character (normal distribution with no trend and a lumpy distribution), the shortage decreased from 18 to 4 days. In drugs in BV group

with a type 4 demand character (non-normal distribution), a small decrease of 15 to 13 days in the shortage was found.

Regarding number of the annual shortage, with the recommended policy instead of the existing Min/Max policy, drugs in BE group with a type 1 demand character experienced a similar level of the shortage which was 752 units. A much larger decrease from 965 to 475 units was found in drugs in BE group with a type 2 demand character. Drugs in BE group with a type 4 demand character experienced a decrease in the shortage from 192 to 52 units.

For the inventory-to-sale ratio, an increase from 0.05 to 0.06 was seen in drugs in BN group with a type 1 demand character. A larger increase, from 0.05 to 0.14, was in the BN group with a type 4 demand character.

In terms of the application of the recommended policy to the drugs with low consumption value (group C), CV group drugs with a type 1 demand character had a five days of shortage which was similar to that of the existing Min/Max policy. Those in CV group with a type 2 demand character experienced a large decrease of 11 to 2 days of shortage; while those with a type 4 demand character faced 14 days of the shortage similar to that of the existing policy.

Regarding number of the annual shortage, with the recommended policy instead of the existing Min/Max policy, drugs in CE group with a type 1 demand character experienced a decrease from 4,570 to 3,765 units; while those with a type 2 demand character had a dramatic decrease from 1,047 to 42 units. Decreases from 6,395 to 5,626 units, and from 14 to 6 units were found in drugs in CE group with types 3 and 4 demand character, respectively.

In terms of the inventory-to-sale ratio, drugs in CN class with a type 1 demand character experienced a slight increase from 0.05 to 0.06. Meanwhile, increases from 0.05 to 0.07 and 0.05 to 0.09 were found in those with types 2 and 4 demand character, respectively.

It could be concluded that the existing Min/Max policy was not suitable for most drugs, but for some with a specific demand character. The application of inventory management policies in the hospital should take the consumption value and clinical importance of individual drugs into account. These unique attributes of drug products made the supply chain of the healthcare products different from those in other industries. In addition, our findings could be properly

applicable to hospitals with high-volume and diverse drug items.

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