Improving the Performance of Procurement and Inventory Management of Hospital Materials (Case of a Taiwanese Medical Centre)

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Abstract. Within healthcare organization, the main goal of material procurement and inventory management is to reduce the cost associated with supplies without sacrificing the quality of patient care. In general, there are two ways to maintain supply level, i.e., joint procurement and direct purchase from the point-of-use location. For joint procurement, the demand of the associated point-of-use will place order to central warehouse. The other way is the order is directly place to the supplier by the individual department. The focus of this study is to examine the current procurement and inventory management and improve the inventory policies for central storeroom and indivual department. To maintain the service by setting new order policies. In this study, we define a performance indicator, supply-demand ratio to measure the improvement of the operation of procurement and inventory management. With new policy, holding cost and idle stock, and usage of space can be reduced meanwhile it can maintain its service level.

1. Introduction
Medication and medical consumables are the core in the service system of hospital, is the core that allow doctors to provide quality service to the patients. To ensure hospital will provide a prompt, accurate, and stable medical treatment, hospital has to establish its own storeroom to manage genetic drugs, medical consumables, vaccination, so forth, and that’s why the issue of inventory management is becoming increasingly crucial. In relevant references discussion, experts indicate that all the drugs and consumables are account for nearly 30 to 40 percent of the operational cost in the hospital in average. Medical Centre, in particular is the leading spearhead in terms of advance medical equipment, quality service, treatment and caretaking, it’s quite conceivable that tremendous scale like this is in urgent need of high demand of medication, and therefore make it much difficult to manage, in this semester, professor assign an industry-university cooperative research project to us in an effort to deeply analysis current supply and demand situation in the hospital, realize the core of reality and give our resolution.

The focus of this thesis paper is on material management in the storeroom, analysis ordering and dispensing receipt, in an effort to establish a much perfect ordering quantity as well as the safety stock to leverage the resources that had been used in the storeroom. Moreover, we wish to prove that whether it is suitable for the upper stream supplier dispensing all the usage directly to the storeroom, then storeroom can effectively dispense to each separate department accordingly; Ultimately minimize stock level in the medicine storeroom.
2. Literature Review
In general, the cost percentage for purchasing the medication and medical material related to the total cost for operating a hospital is account for nearly 30 to 40 percent, for the purchasing cost the medication’s cost occupies 80 percent more [1]. Unfortunately, medical institutes often neglect drug inventory management. In this study, characteristics of medication’s demands are included. Several forecasting models can transform the judgements of physician prescribing behaviours into the knowledge base of the quantifiable doctors and drugs relation matrix. To establish the interactive decision support system, the experimental results show that the interactive decision support system can effectively elevating forecasting accuracy, quality of decision making for reducing the ordering and holding cost.

Since the health insurance and the policy have been implemented by Department of Health, Executive Yuan, bring huge impact on the hospital, especially on the aspect of revenue decrease. The hospital is a high-cost organization formed by human resource, high-tech apparatus, and pharmaceuticals, usually, the cost of human resource and pharmaceuticals, in particular rank 1 and 2, the issues related to cost control and management have been widely discussed in the forum and try to find out a better solution. The focus of this thesis paper is on medical costs, cost control and management is our major concern. Generally speaking, the aspect of cost can be divided into four segments, distribution, stock, operation and procurement, the respective solution are, distribute to the specific spot, outsource the inventory management, operate through electronic commerce, purchase in the form of joint procurement to shave off the cost.

3. Current situation and problem statement

3.1. Scenario
Current pharmaceuticals procurement policy in Medical Centre can generally divide into two categories, joint procurement by the storeroom and direct purchase by each separate department, respectively.

Most orders the storeroom possesses are usually the common used pharmaceutical, apparatus, and consumables in each department, and those orders are jointly procured by the storeroom and directly dispense each demand to the corresponding unit. If the order is only from one single unit or minority requirement then the policy is to procure from the upper stream supplier.

![Figure 1. Procurement process](image)

From the ordering-list and picking-list in two quarters, we discovered that overall there are estimated 2415 types of pharmaceuticals, where 663 of them is from the storeroom and the remaining 1756 is from respective department.

In further digging, one single season demand from the storeroom can up to a staggering 18 million, unsurprisingly, one season demand from individual need is only 160,000, which, comparatively is much lower than the overall amount from joint procurement.
Each department can order up to 4.7 million in one single season, and each order can up to 280,000 in total. Statistics are shown in the following table 1.; Coming up next, we will take a closer look into the aspect of joint procurement and direct procurement, respectively.

### Table 1. Joint procurement& Direct procurement

| Type                  | Joint procurement | Direct purchase |
|-----------------------|-------------------|-----------------|
| category              | High volume, various | Low volume, single |
| First quarter demand  | 18,543,530        | 4,707,307       |
| Maximum order         | 166,400           | 286,170         |

3.2. Problem Statement

3.2.1 Joint procurement

We gather total ordering amount and supply from these 663 types of pharmaceuticals after analysing the pickup-list and ordering-list in two quarters, and sequencing the demand of ordering from the most to the least, and calculating the supply-demand ratio (table 2.), where, the result shows that the supply-demand ratio of the leading order amount is lie at exactly 2.0. Although, in general, ratio is lie at roughly 1.98 in two quarters. More specifically, this statistical result implies that the storeroom is ordering two times each individual department reportedly need, if we transform our findings into the bar chart (figure 2.) which can make more logical sense, in addition, high inventory level means high holding and set-up cost.

### Table 2. supply-demand ratio

| Item code | Q1 demand | Q1 order quantity | Q2 demand | Q2 order quantity | Total demand | Total order | ratio |
|-----------|-----------|-------------------|-----------|-------------------|--------------|-------------|-------|
| CI0004001010 | 1803754 | 3827200          | 1905324   | 3827200          | 3709078      | 7654400    | 2.06  |
| C01000012055 | 1030563 | 1860000          | 975975    | 1860000          | 2006538      | 3720000    | 1.85  |
| C01000012068 | 643847  | 1155000          | 541327    | 1155000          | 1185174      | 2310000    | 1.95  |
| CJ5200012021 | 365030  | 741120           | 400686    | 741120           | 765716       | 1482240    | 1.94  |
| CJ2800007017 | 222066  | 403200           | 185046    | 403200           | 407112       | 806400     | 1.98  |
| C03004007016 | 181500  | 350000           | 157501    | 350000           | 339001       | 700000     | 2.06  |
| ...         | ...      | ...              | ...       | ...              | ...          | ...        | ...   |
| C01000012013 | 148455  | 345000           | 158114    | 345000           | 306569       | 690000     | 2.25  |
| total       | 9395029  | 18543530         | 9377396   | 18543530         | 18772425     | 37087060   | 1.98  |

3.2.2 Joint procurement-department requirements

The above-cited order-supply situation is analysis from the angle of material, in the following discussion we will see it from the angle of drug usage by each department, we take the top 10 department that leads the drug supplement in quantity as our example, summary in table 3; Furthermore, we will take one step further to look into the top 10 drug types in this ten department as another example, see in table 4.

Lastly, we excavate two pivotal issues, the first is to show that national holidays or weekends will somehow influence application, usually because a lack of human resource during consecutive holidays and supplier is also out of position, in order to prevent stock-out and operational purpose, each department will apply large amount of medication prior to the holidays.

Second hugely influential problem is tremendous application often came out of the blue. In detail, we found out something a bit peculiar is, in fact, there isn’t a consecutive holiday but still show a high ordering quantity. The sudden high demand along with bullwhip effect will cause a huge burden for the warehouse and supplier because they both got no idea when is the proper timing to replenish or distribute. To cope with the above-cited circumstances, high inventory level seems to be the only way
out, however, this will directly lead to high inventory cost and management difficulty, which is the typical downside that most company confronted.

![Figure 2. Demand and Order Quantity](image)

**Table 3.** Top 10 department that leads the drug supplement in quantity

| No | User Point | Drug Types | Demand  |
|----|------------|------------|---------|
| 1  | ERN1       | 342        | 1384371 |
| 2  | ICU        | 255        | 721912  |
| 3  | SICU       | 291        | 686739  |
| 4  | W65        | 284        | 646549  |
| 5  | RICU       | 251        | 601213  |
| 6  | HD         | 144        | 595849  |
| 7  | W105       | 268        | 595460  |
| 8  | W55        | 275        | 539925  |
| 9  | COL        | 29         | 529508  |
| 10 | W86        | 285        | 514229  |

**Table 4.** Top 10 demand drug types

| Item Code     | Total |
|---------------|-------|
| CI0004001010  | 1490065|
| C01000012055  | 999353 |
| C01000012068  | 340619 |
| CJ5200012021  | 192470 |
| CJ5860017016  | 142955 |
| CJ2910001022  | 124498 |
| CJ5860017032  | 117900 |
| CA1675006034  | 116000 |
| CJ5300001019  | 102532 |
| CJ5860004015  | 99700  |

3.2.3 Problem statement

Statement: 1. Correlation between consecutive holiday and the amount of order.

Take department ERN1 as the following example, figure 3. give a clear outlook of the amount of order. Red circle highlights two dates just two weeks before the national new year holiday, and as you
can see, something unusual quickly catch our attention, normally from early January to late June, the amount of order were ranging from 0 to 25000, but before holidays the amount were suddenly rising up to more than 20000.

![ERN1 daily order amount](image1)

**Figure 3. ERN1 daily order amount**

Statement: 2. tremendous application amount

In this context, take department W65 as the following example, meanwhile, figure 4 gives a complete outlook of respective amount of order in this two department, respectively. First of all, the situation is quite the opposite to the previous one, where there is no weekends or holidays when the amount of order rising unexpectedly, however, the amount rising is actually due to the urgent requirements on certain specific items. More specifically, code C01000012068 is applied normally at 1500 level when the ordering period is 4 to 6 days, on May 1st. We had 10000, and the next ordering date initially should be on May 7th, but since May 1st, the graph pointed out that June 8th is the anticipated date to order, which clearly against the ordering period, 4 to 6 days.

![W65 daily order amount](image2)

**Figure 4. W65 daily order amount**

### 3.2.4 Joint procurement-ordered by the medical storeroom

Coming up next we will take a different look from the angle of the medical storeroom in terms of the top 10 drug types which lead the application in amount. Same process, just the different trigger, we found out three primary questions in our observation.

The first question was how consecutive holidays influenced the amount of order; the second was about ordering by the rule of thumb. Lastly, it’s a very common issue, high level of inventory.

### 3.2.5 Problem statement

Statement: 1. Correlation between consecutive holiday and the amount of order.
Take material C01000012068 for example, as you can clearly see in figure 5., which gives a clear outlook of the correlation between inventory and demand in the first quarter, furthermore, there were three highest points during the consecutive holidays in February, where inventory is far higher than average, from further analysis we discovered the average ordering amount was 25,000, but in February the amount increasing tremendously to one hundred thousand, which was four times the average amount.

![Inventory build-up diagram of item C01000012068](image)

**Figure 5.** Inventory build-up diagram of item C01000012068

Statement: 2. Rule of thumb and 3. high level inventory

Problem 2 and 3 are highly associated, therefore, in this section, we will deeply analysis this two collectively. Take material C03004007016 for example, figure 6. gives a clear outlook on the relationship between inventory and demand from the early January to the end of June; Highest inventory remained at 30,000 in the first quarter, where the amount of ordering was at 25,000. Moving on to the second quarter, on March 27th, the amount of ordering was at 50,000, which doubles the amount of the previous quarter. We anticipated that due to a lack of material stored in the warehouse is the reason why each department thought they will have difficulty distributing the right amount, as a result, in the second quarter they decided to order double quantity to cope with shortage issue, averaging 7000 in amount of order, but the inventory was more than five times the amount of order, which was 40,000.

![Inventory build-up diagram of item C03004007016](image)

**Figure 6.** Inventory build-up diagram of item C03004007016

3.3. Brief conclusion

Generally speaking, according to the explanation of the demonstration of problems we showcase above, the problem can be divided into two aspects, medical storeroom and the individual department, since the amount and the types of drug is immense and complex, in order to prevent any shortage situation, medical storeroom tend to order huge amount of drugs which often lead to high inventory level,
meanwhile, sometimes makes it hard to integrate the requirements of specific drug usage, and the adverse impact from the bullwhip effect directly influence the upper stream supplier who can’t control the timing and the amount of the standard of inventory.

4. Mathematical model
To solve the problem caused by high inventory and rule of thumb, we calculate the economic ordering quantity and establish safety stock base on the aggregation of the demand from each department, we hope that we can successfully reduce the level of inventory, meanwhile maintaining at a normal inventory level. In this thesis paper we take top 10 department which lead the amount in application as our experimental example.

\[
EOQ_{ij} = \sqrt{\frac{2 \left(\frac{d_{ij}}{u_j}\right) s}{H}} \\
(1)
\]

\[
f_{ij} = \frac{d_{ij}}{EOQ_{ij}} \\
(2)
\]

\[
S_j = \sum_{i=1}^{n} \sum_{j=1}^{m} EOQ_{ij} * u_j * f_{ij} \\
(3)
\]

Formula explanation:
- \(d_{ij}\) = demand of item (j) in user point (i)
- \(u_j\) = item (j) ordering unit
- \(f_{ij}\) = order frequency of item (j) in user point (i)
- \(H\) = holding cost
- \(s\) = cost per unit
- \(S_j\) = Purchase quantity of item (j)
- \(EOQ_{ij}\) = Economic Ordering Quantity of item (j) in user point (i)

We calculate the economic ordering quantity base on the demand of drugs in two quarters, compute the summation of the ordering amount in the medical storeroom base on 10 respective department, however, because the data of holding cost and set-up cost are considered to be highly classified or the types of drug is too complicated, as a result, in our research, with limited cost data sources, we can only calculate the EOQ and the safety stock base on the information of ordering list and pick-up list in the storeroom, with the unknown holding and set-up cost, we assume that the holding cost is closely equal to set-up cost.

According to the above formula we can automatically calculate the economic ordering quantity and ordering period by a process of mathematical computation, well eventually we will be pleased to compare the improvement benefit, where our goal is to reduce the amount of ordering, take department ERN1 for example. In table 5, we can clearly see the statistic figure of EOQ, frequency, the amount of order and the ordering period, each drug will be ordered by the factor of 100, each department can be dramatically different in the amount of ordering due to completely different demand, after progression, the original amount of ordering at department ERN1 is decreasing largely from 7000 to about 3700, and material is ordering at a stable rate (figure 7.). After improvement, the supply-demand ratio is down to nearly close to 1 (figure 8.), which is what we truly want to see.
### Table 5. Economic Ordering Quantity of all item

| Item code       | \( u_j \) | \( EOQ \) | \( f_{ij} \) | order | Period (days) | Total  |
|-----------------|-----------|---------|-------------|-------|---------------|--------|
| CI0004001010    | 100       | 80      | 40          | 8000  | 4             | 320000 |
| CJ2910001022    | 100       | 50      | 25          | 5000  | 7             | 125000 |
| C01000012055    | 100       | 45      | 22          | 4500  | 8             | 99000  |
| C01000012068    | 100       | 34      | 17          | 3400  | 10            | 57800  |
| CJ5860017016    | 100       | 30      | 15          | 3000  | 12            | 45000  |
| CI9999015022    | 100       | 28      | 14          | 2800  | 12            | 39200  |
| CJ5860017032    | 100       | 28      | 14          | 2800  | 12            | 39200  |
| CA1675007013    | 100       | 26      | 13          | 2600  | 13            | 33800  |
| CJ5440005012    | 100       | 25      | 12          | 2500  | 15            | 30000  |
| C01000012042    | 100       | 25      | 12          | 2500  | 15            | 30000  |

#### Figure 7. Daily Order Quantity from ERN1 after improvement

#### Figure 8. Demand and Order Quantity after improvement

5. **Conclusion and future expectancy**

Within healthcare organization, the main goal of material procurement and inventory management is to reduce the cost associated with supplies without sacrificing the quality of patient care. It is a challenge of the risk of shortage or high-level inventory. The easiest way is to set up a high inventory level to avoid and shortage. However, the high holding cost and the waste of idleness will reduce the profit margin of the healthcare organization. Therefore, the purpose of this research is to improve the procurement and inventory operations by setting new inventory policy, meanwhile maintaining the
inventory level. We significantly reduce the supply-demand ratio from the original 1.98 down to a logical 1.04, however not all the drugs or materials is suitable for this approach.

Future improvement can reduce the preserved consumables. The amount of medical consumables in the warehouse that can produce extra space for other urgent pharmaceuticals. The outsourcing strategy can be applied. That is supplier can distribute each individual demand directly to each department accordingly.

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