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# An Application of the Inventory Models to the Intravenous Fluids Subsystem

Young Min Kim*

**Abstract**

Life and death often depend upon the efficiency of the hospital operations. By applying the inventory models to the Intravenous fluids subsystem, the Intravenous fluids inventory operation can be systemized and made to run with less management effort and with far greater precision. And most important of all, this more precise form of control can help assure a greater degree of availability of critically needed items of the Intravenous fluids.

## Introduction

The special and vital function of the I.V. solutions makes availability of these fluids when needed a paramount concern in con trolling these inventories. The penalty of running out of the I.V. solutions for the hospital may have to be measured in terms of a social cost of pain or possible death. Thus, an applicable Inventory Models should be able to respond quickly to the most recent withdrawals and their fluctuations.

## An Application of the Inventory Models

Bridgeport Hospital is a voluntary, non-profit, general hospital providing health care to residents of the greater Bridgeport areas. Founded in 1884 with 48 beds and P.T. Barnum as its first president, the hospital was built and equipped with contributions from local industries and private citizens. Today, the ten-story Bridgeport Hospital with accommodations for 485 patients is still expanding with the current building program of the ten-story twin-tower addition, $15 million constructions, which is scheduled for completion in January of 1975.

According to the Purchasing Department of the hospital, Bridgeport Hospital supplies consist of approximately 1,300 individual items. The inventory investment ranges between $128,000 and $133,000. Monthly usage approximates $68,000. There are eleven supply categories. Medical-Surgical, Laboratory, Intravenous Solutions and Sets, Groceries, Fruits and Vegetables, Formulas, Household, Linen, China, Stationery, and Printed Forms. And also there are non-stock or "Hold-in-Stores" items.

The I.V. Solutions Subsystem consists of approximately 80 different individual items involving more than 20 separate departments. Clearly, not all items deserve equal attention or equal refinement of control. It is generally found that a relatively small proportion of the items accounts for a rather large

Department of Industrial Engineering, Inha Universit

proportion of the total usage. For example, one frequently hears that 20 per cent of the items accounts for 80 per cent of the usage. Under such circumstances, the small fraction of items of heavy usage deserve most of the inventory management attention, and the large number of low usage items can be carried on rather abundant supply with a relatively low inventory invesment, thus avoiding the need to devote much management attention to their control. And also since many departments are involved, there should be an evaluation of organization functions in order to establish the control points.

Therefore, before applying Inventory Models, the following data are required.

1. The usage rate and its variations. The rate at which the items in this subsytem are being withdrawn should be known that forecast of future demands, buffer stock levels, the classifications of the items and departments, etc. could be derived.

2. Costs associated with the operations of the I.V. Fluids Subsystem. There are costs associated not only with the ordering and storage but also with handling, obsolescence, damage, insurance, and spoilage.

3. Storage capacities at such control points as Storeroom, Central Supply, and Patients floors.

4. There should be a historical data concerning the lead time—the time lag between placing a reorder and receiving it.

5. The costs of goods themselves and quantity discount data should be available.

From Table 1, the items in the I.V. Fluids Subsystem could be divided into three groups according to their rate of usage, the so-called A, B, C classification. The A group is consisted of those items (perhaps 10 to 15 per cent of the total) which account for about 50 per cent of the total usage. The C group is made up of about 50 per cent of items of least usage. And the B group is comprised of the remainder. Therefore, the followings are obtained:

Table 3......Items in the A group
Table 4......Items in the B group
Table 5......Items in the C group.

**Table 1. TOTAL WITHDRAWLS DURING APRIL 5, 1974 THRU MAY 30, 1974**

| Item No. | 4/5 | 4/12 | 4/19 | 4/26 | 5/3 | 5/10 | 5/17 | 5/24 | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | — | — | 1 | — | — | — | — | — | 1 | — |
| 170 | — | 1 | — | — | — | — | — | — | 1 | — |
| 180 | 3 | 6 | 1 | 8 | 2 | 1 | 2 | 3 | 26 | 1.0 |
| 182 | 24 | 15 | 12 | 20 | 48 | — | — | 12 | 131 | 5.4 |
| 210 | 5 | 3 | 1 | — | 5 | 4 | — | 1 | 19 | — |
| 212 | 3 | 1 | 2 | 9 | 4 | 5 | 7 | 5 | 36 | 1.3 |
| 220 | 1 | — | 1 | 1 | 1 | — | — | — | 4 | — |
| 240 | 11 | 20 | 11 | 15 | 18 | 25 | 8 | 16 | 125 | 5.1 |
| 250 | — | — | — | — | 1 | — | 1 | — | 2 | — |
| 260 | 2 | 3 | 1 | 2 | 1 | 6 | 2 | 5 | 22 | 0.9 |
| 270 | — | — | — | — | — | 1 | — | — | 1 | — |
| 280 | 3 | 1 | — | — | 1 | 1 | — | — | 6 | — |
| 290 | — | — | — | — | 1 | — | — | — | 1 | — |
| 300 | 30 | 27 | 9 | 22 | 18 | — | — | — | 171 | 7.0 |
| 310 | 26 | 5 | 19 | 22 | 25 | 26 | 7 | 2 | 136 | 5.2 |
| 320 | 75 | 58 | 37 | 59 | 74 | 76 | 57 | 63 | 449 | 20.8 |
| 340 | — | — | — | 1 | — | — | 10 | 2 | 13 | 0.5 |
| 350 | — | 1 | — | — | 2 | 2 | 2 | 1 | 8 | — |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 360 | — | — | — | — | 1 | — | — | — | 1 | — |
| 370 | 2 | — | — | 2 | — | 3 | 3 | — | 10 | — |
| 380 | — | — | — | — | — | 2 | — | — | 2 | — |
| 388 | 1 | — | 1 | 1 | 1 | 2 | 1 | 1 | 8 | — |
| 390 | 49 | 41 | 57 | 45 | 62 | 51 | 50 | 62 | 417 | 17. 2 |
| 420 | — | — | — | — | — | — | — | 1 | 1 | — |
| 430 | 1 | — | — | — | 1 | — | 1 | — | 3 | — |
| 440 | — | — | — | — | — | 1 | — | 11 | 12 | — |
| 500 | 2 | — | — | — | 1 | — | — | 2 | 5 | — |
| 510 | 23 | 10 | 16 | 18 | 21 | 16 | 15 | 9 | 128 | 5. 3 |
| 528 | — | 2 | 1 | 2 | 2 | 1 | 3 | 2 | 13 | — |
| 530 | 2 | 1 | — | — | 1 | 1 | — | — | 5 | — |
| 540 | 22 | 11 | 12 | 8 | 10 | 21 | 6 | 20 | 110 | 4. 5 |
| 550 | 1 | — | 3 | 1 | 1 | 2 | 4 | 1 | 13 | — |
| 560 | 12 | 7 | 4 | 6 | 7 | 15 | 3 | 8 | 62 | 2. 6 |
| 565 | — | 1 | — | 2 | — | — | — | 1 | 4 | — |
| 630 | — | 1 | 1 | 1 | 2 | — | — | 2 | 7 | — |
| 650 | — | — | 2 | 1 | 2 | 3 | — | 2 | 10 | — |
| 655 | 3 | — | — | 2 | — | 2 | 2 | — | 9 | — |
| 660 | 22 | 33 | 43 | 37 | 44 | 44 | 44 | 44 | 311 | 12. 8 |
| 690 | 15 | 5— | 4 | 14 | 4 | 6 | 14 | 6 | 68 | 2. 8 |
| 700 | — | 2 | — | 3 | 3 | 2 | 2 | 3 | 15 | — |
| 702 | 1 | — | — | — | — | — | 1 | — | 2 | — |
| 710 | — | — | — | — | 1 | — | — | — | 1 | — |
| 760 | 2 | — | — | 2 | — | — | — | — | 4 | — |
| 780 | — | — | — | — | — | — | — | 1 | 1 | — |
| Total | 341 | 255 | 239 | 304 | 365 | 348 | 253 | 318 | 2, 423 | 100 |

| Item No. | Item | Size |
|---|---|---|
| 100 | 5% Alcohol 5% Dextrose In Normal Saline w/Vitamins | 1, 000cc |
| 170 | Blood Collection Set | 36/Case |
| 180 | Administration Set & Pump Blood Solution Y Type | 48/case |
| 210 | 5% Dextrose Electrolyte #75 | 500cc |
| 220 | 5% Dextrose Electrolyte #48 | 250cc |
| 240 | 5% Dextrose In Normal Saline | 1, 000cc |
| 250 | 10% Dextrose In Normal Saline | 1, 000cc |
| 260 | 5% Dextrose In Saline | 500cc |
| 270 | 10% Dextrose In Saline | 500cc |
| 280 | 5% Dextrose In 0. 3390 Sodium Chloride | 250cc |
| 290 | 5% Dextrose In 0. 3390 Sodium Chloride | 500cc |
| 300 | 5% Dextrose In Water | 250cc |
| 310 | 5% Dextrose In Water | 500cc |
| 320 | 5% Dextrose In Water | 1, 000cc |
| 340 | 10% Dextrose In Water | 500cc |
| 350 | 10% Dextrose In Water | 1, 000cc |
| 360 | 20% Dextose In Water | 500cc |
| 370 | Distilled Water | 500cc |
| 380 | Distilled Water | 1, 000cc |
| 390 | Distilled Water Pour Bottle | 1, 000cc |
| 420 | 6% Gentraw In Nomal Saline | 500cc |
| 430 | 15% Glycine In Water | 1, 000cc |
| 440 | Hypodermoclysis Y Type Administrative Set | 36/case |
| 500 | Lactated Ringers | 500cc |
| 510 | Lactated Ringers | 1, 000cc |
| 520 | 10% Levogen In Water | 1, 000cc |
| 530 | Minimeter Set Adapter | 36/case |
| 540 | Normal Saline | 250cc |
| 550 | Normal Saline | 500cc |
| 630 | Plasma Vac Cont'r Empty | 1, 000cc |
| 650 | Sodium Chloride Pour Bottle | 500cc |
| 660 | Sodium Chloride Pour Bottle | 1, 000cc |
| 690 | Solution Administration Set | 36/case |
| 700 | Solution Series Set | 36/case |
| 710 | Transfuso w/Acid Solution Vac Container | 500cc |
| 760 | Chloride 0. 45% Sod. Chlo. 10% Travert 0. 390 Potassium | 1, 000cc |
| 780 | Urologic Solution G | 1, 000cc |

**Table 2. TOTAL WITHDRAWALS BY DEPT. FROM 4/5/74 TO 5/30/74**

| Item No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | — | 1 | — | — | — | — | — | — | — | — |
| 170 | — | 1 | — | — | — | — | — | — | — | — |
| 180 | 6 | 12 | — | 8 | — | — | — | — | — | — |
| 182 | — | 129 | — | 2 | — | — | — | — | — | — |
| 210 | — | 13 | — | — | — | — | 6 | — | — | — |
| 212 | — | 36 | — | — | — | — | — | — | — | — |
| 220 | — | 1 | — | — | — | — | 3 | — | — | — |
| 240 | 3 | 52 | — | — | — | — | — | — | 69 | — |
| 250 | — | 2 | — | — | — | — | — | — | — | — |
| 260 | — | 6 | — | — | — | — | — | — | 16 | — |
| 270 | — | 1 | — | — | — | — | — | — | — | — |
| 280 | — | 2 | — | — | — | — | 4 | — | — | — |
| 290 | — | 1 | — | — | — | — | — | — | — | — |
| 300 | — | 171 | — | — | — | — | — | — | — | — |
| 310 | 65 | 47 | — | — | — | — | 1 | — | 23 | — |
| 320 | 59 | 235 | — | — | — | — | — | — | 205 | — |
| 340 | 10 | 3 | — | — | — | — | — | — | — | — |
| 350 | — | 8 | — | — | — | — | — | — | — | — |
| 360 | — | 1 | — | — | — | — | — | — | — | — |
| 370 | 10 | — | — | — | — | — | — | — | — | — |
| 380 | — | — | — | — | — | — | 2 | — | — | — |
| 388 | — | 7 | — | — | — | — | — | — | — | 1 |
| 390 | — | 126 | 26 | 4 | — | 160 | 12 | 3 | 38 | 48 |
| 420 | — | 1 | — | — | — | — | — | — | — | — |
| 430 | — | 3 | — | — | — | — | — | — | — | — |
| 440 | — | 2 | — | — | — | — | — | — | 10 | — |
| 500 | — | 5 | — | — | — | — | — | — | — | — |
| 510 | 65 | 33 | — | — | — | — | — | — | 30 | — |
| 528 | — | 13 | — | — | — | — | — | — | — | — |
| 530 | — | 3 | — | — | — | — | 2 | — | — | — |
| 540 | — | 82 | — | 27 | — | — | 1 | — | — | — |
| 550 | — | 3 | — | — | — | — | — | — | 11 | — |
| 560 | — | 34 | — | — | — | — | — | — | 29 | — |
| 565 | — | — | — | — | 4 | — | — | — | — | — |
| 630 | — | 7 | — | — | — | — | — | — | — | — |
| 650 | — | 9 | 1 | — | — | — | — | — | — | — |
| 655 | — | 9 | — | — | — | — | — | — | — | — |
| 660 | — | 53 | — | 35 | — | 160 | 7 | — | 56 | — |
| 690 | 22 | 24 | — | — | — | — | 2 | — | 20 | — |
| 700 | — | 2 | — | — | — | — | — | — | 13 | — |
| 702 | — | 2 | — | — | — | — | — | — | — | — |
| 710 | — | 1 | — | — | — | — | — | — | — | — |
| 760 | — | 4 | — | — | — | — | — | — | — | — |
| 780 | — | 1 | — | — | — | — | — | — | — | — |
| Total | 240 | 1,146 | 27 | 76 | 4 | 320 | 40 | 3 | 520 | 49 |
| % | 9.9 | 47.2 | 1.0 | 3.0 | — | 13.2 | 1.5 | — | 21.4 | 2.0 |

where Department 1 : Anesthesia
2 : Central Supply
3 : Inhalation Therapy
4 : Laboratory
5 : New Born Intensive Care Unit
6 : Operating Room
7 : Pediatrics
8 : Pharmacy
9 : Richardson 7, 8, 9, and 10 Schine 4, 5, 7, 8, 9, and 10
10 : Urology

**Table 3. Items In the "A" Group**

| Item No. | # of Usage | % |
|---|---|---|
| 300 | 171 | 7.0 |
| 320 | 499 | 20.8 |
| 390 | 417 | 17.2 |
| 600 | 311 | 12.8 |
| Total | 1,398 | 57.8 |

**Table 4. Items In the "B" Group**

| Item No. | # of Usage | % |
|---|---|---|
| 180 | 26 | 1.1 |
| 182 | 131 | 5.4 |
| 212 | 36 | 1.5 |
| 240 | 124 | 5.2 |
| 260 | 22 | 0.9 |
| 310 | 136 | 5.6 |
| 510 | 128 | 5.2 |
| 540 | 110 | 4.5 |
| 560 | 63 | 2.6 |
| 690 | 68 | 2.8 |
| Tota | 844 | 34.8 |

**Table 5. Items In The "C" Group**

| Item No. | # of Usage | % |
|---|---|---|
| 100 | 1 | * |
| 170 | 1 | |
| 210 | 19 | |
| 220 | 4 | |
| 250 | 2 | |
| 270 | 1 | |
| 280 | 6 | |
| 290 | 1 | |
| 340 | 13 | |
| 350 | 8 | |
| 360 | 1 | |
| 370 | 10 | |
| 380 | 2 | |
| 388 | 8 | |
| 420 | 1 | |
| 430 | 3 | |
| 440 | 12 | |
| 500 | 5 | |
| 565 | 5 | |
| 630 | 7 | |
| 650 | 10 | |
| 655 | 9 | |
| 700 | 15 | |
| 710 | 2 | |
| 760 | 1 | |
| 780 | 4 | |
| Total | 131 | 7.5% |

* Very small figures

Storeroom has approximately 10,970 square feet and 106,949 cubic feet of potentially usable storage space. But no data was available concerning the storage space for the I.V. fluids at Storeroom. At Central Supply there was no data available either. At the patient floors it it even difficult to store about 48 or 54 bottles of the fluids which were used quite frequently.

With the eight week data of withdrawals, it was mpossible to obtain any meaningful distribution pattern. Thus it is quite necessary to expand withdrawal data in order to derive the meaningful buffer stock levels at Storeroom, Central Supply, and ten Patient floors.

## Recommendations

Even with this limited data of eight week withdrawals, it is quite clear not all items deserve equal attention or equal refinement of control. As shown in Table 3, 4, and 5, the A group contains four items which account for 57.8 per cent of the total withdrawal, the B group is comprised of ten items and 34.8 per cent of the total withdrawal, and C group is made up of thirty items of least usage of 7.5 per cent. The A group should be given the careful control that the usage rates of its items are monitored carefully and reviewed periodically. The C group items are perhaps controlled by a much simpler set of decision rules, because of their relatively low usage rates. The B group items could be controlled with asimplified form of control used for class A items.

Since the vital function of the I.V. Solutions makes availability of these fluids when needed a paramount concern, an applicable Inventory Model should consider such factors as ability to respond quickly to recent withdrawals and no shortage and stock-outs. Thus, the replenishment model is most suitable to the A group items. In order to apply the replenishment model it is recommended that the usage rates of its items should be monitored and reviewed carefully, the variability of their usage rates is calculated, and safety stocks, the buffer stock levels, are provided on a carefully calculated basis through the meaningful distribution analysis.

For the A group items, the followings are derived from the Table 1 :

| Item No. | Average Withdrawal per Day | Buffer Stock Level |
|---|---|---|
| 300 | 3 | 14 |
| 320 | 9 | 17 |
| 390 | 7 | 16 |
| 660 | 6 | 13 |

And also for the A group items, it is assumed that the lead time (L) be 3 days, the review time (R) be 14 days, and the inventory levels as of April 5, 1974 be 50, 150, 110, and 100 for item numbers 300, 320, 390, and 660 respectively. With these data the replenishment models are applied to the A group items as illustrated in the Figures 1 and 2.

For the C group items, the fixed order quantity model is more suitable. Because of their relatively low usage rates, the C group items could be carried in rather abundant, but within the statutory limitation, supply with a relatively low inventory investment. This system of ordering the economic (fixed) order quantity model would avoid the need to devote much manangement attention to their control. For the B group items, a simple version of the replenishment model would preferable by putting less emphasis on the buffer stock levels but concentrating to the replenishment lead time.

As shown in the Table 2, Central Supply receives about 47.2 per cent of the total withdrawal from Storeroom and then those items are sent to various "customer" departments upon telephone requests via Transportation Department. This could be reduced by increasing direct deliveries to the "customer" departments. Presently, no Patient Floors–Richardson 7, 8, 9, and 10 and Schine 4, 5, 6, 7, 8, 9, and 10–receives Item Numbers 182, 300, and 540 directly from Storeroom. A careful monitoring system at Central Supply would identify the heavy users of those items and make it possible to deliver those items directly to the specific

**Figure 1. The Replenishmet Model for Item 300**

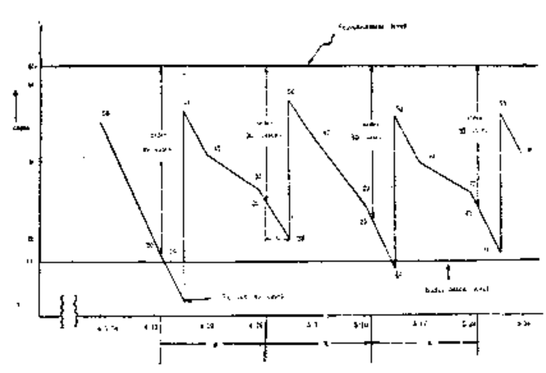
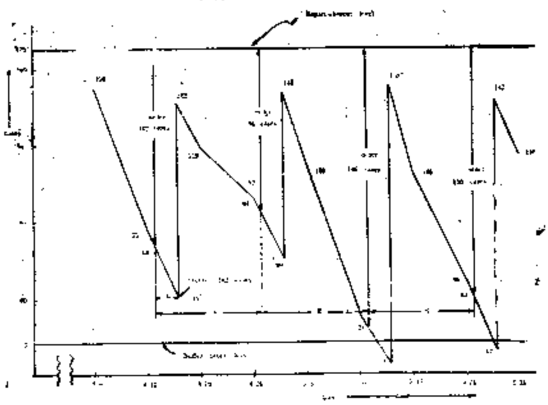


**Figure 2. The Replenishment Model for Item 320**



"customer" departments from Storeroom. And also for Item Numbers 320 and 390 direct deliveries from Storeroom to the various "customer" departments should be increased.

1. It is recommended that the futuie inventory models be expanded and refined so as make more accurate assessment of demand forecasts, variables such as number of patients, the characteristics of patients, and so forth.

2. It is recommended that the future models be applicable to other ten supply categories.

3. It is recommended that for the future models, care be taken in planning the model well in advance of the data collection, to insure that the necessary data are being recorded properly to minimized the possibility of introducing data-related bias into the system.

4. It is recommended that the future models based upon a data system built around a set of records, machine or manual, which provides information on the stock levels and usages of the separate items in the inventory.

5. It is recommended that the application of inventory models, regardless of the model used, be kept in a state of active development.

## Summary and Conclusions

Life and death often depand upon the efficiency of the hospital operations. One of the positive and constructive steps which would eliminate cause for inefficient hospital operations is to apply the scientific principles which have been used quite extensively in management of the industrial enterprises. Although it does not have the same profit maximization objective, the hospital is generally faced with the same resource allocation problems like its industrial cousins. Resources are limited, and the hospital should also allocatate them a way to obtain the greatest total utility.

After examining the essential and historically-rooted characteristics of the hospital and supply system, this application of inventory models to the Intravenous Solutions Subsystem would bring the following advantages to the hospital;

1. The Intravenous Solutions inventory operation can be systemized and made to run with less management effort and with far greater precision.

2. A better balance among the items in the inventory can be achieved because fewer stock-outs will occur and fewer surpluses of the inventory will result.

3. Inventory investment can be reduced and the costs of operating the inventory can be cut.

4. Duplication in the inventory can be easily spotted and eliminated.

5. Most important of all, this more precise form of control can help assure a greater degree of availability of critically needed items of the Intravenous Fluids.

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