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Health Care Supply Chain Dynamics: Systems Design of An American Health Care Provider

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Abstract

Health care organizations supply chains are more problematic to manage compare to its industrial counterparts. Moreover, health care organizations have very little control over the demand of supplies. In this paper we propose an integrated system dynamics framework for analyzing and modeling health care logistics chain. An American health care provider is used as an example to demonstrate the implementation of various stages of our framework. Based on the systems analyses, causal relationships were developed and an EOQ based computer simulation model was built and tested. The analyses of the results revealed that the existing "push" type inventory control policies are not suitable for the type of demand that is usually experienced by the health care systems. The authors further suggest that in the health care sector, inventory management should be based on ranking items in terms of "value" and "criticality" rather "frequency of use" to develop appropriate stocking policy.

Keywords: health care logistics, system dynamics, causal-loop diagram, dynamic analysis, EOQ

1 Introduction

Health care is believed to be one of the largest sectors of the service industry in the world. Offering health care and developing health services are considered fundamental national duties, and attract large amount of resources and corporate governance efforts around the world. Health care constitutes one of the largest financial involvements in the United States where according to recent statistics health care spending as a percent of GDP is 12.9 compared to: 10.4 in Switzerland, 10.3 in Germany, 9.3 in France, 9.3 in Canada, and 6.8 in the United Kingdom (OECD Health Data 2001). In the United States, hospital spending continues to consume the largest portion of the health care spending -$ 371 billion in 1997 (Iglehart, 1999). It is estimated that 30-50 percent of hospital spending is related to materials, equipment, and purchased services, such that approximately half of this amount derives from the direct cost of acquiring materials and services, and the other half from the cost of managing them after acquisition (Scheyer, 1995).

Due to population demographics, governments around the globe are under constant pressure to enhance the quality and efficiency of care within the given resources. This paper highlights some strategies for cost reduction while maintaining a reasonable service scenario through system dynamics analysis. Specifically, the paper discusses the implementation details of a system dynamics framework to evaluate inventory management strategies in a children hospital's logistics supply chain.

2 Health Care Logistics

Health care supply chain management is considered more problematic compare to industrial sector. This is due to the wide product range, the criticality of and the perceived need to supply very high levels of services for each item, and the high value of products (Beier, 1995). In many industries, fluctuations in demand can be linked to specific factors that can be controlled to some extent (Smith, 1999). However, health care organizations have very little control over the demand for supplies. In our view, this is due to the fact that health care industry is unique in the volume of diverse support services required to deliver the end product –patient care.

Our experience suggests that even in a more stable demand scenario, supply chains- are difficult to manage and design due to the complexity arising from the human, organization and technology interactions (Hafeez et al., 1996). For example, for managing a logistics operation, managers have to decide on inventory levels, number of warehouses, the size of the buffers, transportation and delivery frequencies, warehouse locations, to manage critical and acute demand fluctuations (Seppälä and Holmström, 1995). As well as, the decision-maker has to take into account information and material as well as cash flows, which is proving to be the major constraint in the system. Usually the absence of a compatible operating strategy results in the poor performance in terms of longer lead times, higher costs, alternating periods of over-capacity followed by under-capacity, and inventory piling up at each tier of the chain. This would affect the performance of the health care industry by stock out situation and subsequently impacting lower level of patient care that could be very detrimental in acute treatment situations.

3 Research Methodology

Towill et al. (1992) suggest that, wherever possible, supply chain operation should be simplified via top-down design followed by bottom-up implementation. Towill (1996) subsequently argue that such redesign requires modeling of existing or proposed supply chains, followed by dynamic simulation in order to synthesize alternative strategies. In this paper, the modeling and simulation of the dynamic behavior of hospital logistics supply chains is conducted by adopting a supply chain modeling and re-engineering methodology as described by Hafeez et al. (1996). Figure 1 illustrates the salient features of an integrated system dynamics framework that was used to model and simulate a steel industry supply chain. The framework consists of several steps, which go under two overlapping phases: qualitative phase and quantitative phase. Although various stages involved are shown as sequential activities, the method is an iterative procedure, which is represented by the feedback loops in Figure 1.

Essentially the framework decomposes the design problem into two parts: conceptual problem and technical problem and thereby recommends using qualitative and quantitative phase to negotiate the respective problems. The qualitative phase is related to acquiring sufficient intuitive and conceptual knowledge to understand the structure and operation of the supply chain, which in turn can help us in recognizing and defining the conceptual problem. Based on the knowledge acquired from performing system analysis on the supply chain, the main variables that have a dominant impact on the functioning and performance of the supply chain are sought and relative cause and effect relationships and other interactions are mapped into information-feedback loops.

The conceptual understanding sets the scene to solve the associated technical problem. The quantitative phase concerns the development and analysis of mathematical and simulation models. The first step towards the quantitative model building is to transform the conceptual causal loop diagrams into block diagrams, which is verified from the concerned people. Subsequently, the key relationships are formulated in a mathematical form using control theory procedures, which is to be validated using field data. The model now can be subjected to a detailed dynamic analysis to represent the time behavior of the supply chain, and suggest improving strategies by fine tuning the existing parameters, or redesigning its structure, or exploring different what-if scenarios.

4 The Case Study

Purchasing in the USA health sector is a relatively mature area. Usually small or medium sized hospitals increase their buying power by forming a group purchasing organization (GPO). The buying power of large GPOs is impressive by creating tremendous value through their scale advantage, giving smaller hospitals the opportunity to buy like big hospitals, and big hospitals the chance to buy like mega-chains (Chapman et al., 1998). However, there is some cost associated in belonging to a GPO, that include the direct cost of membership –usually expressed as an annual fee- and a certain loss of control in product selection (Scheyer, 1995). The members of GPO’s need to meet periodically to evaluate vendor proposals, products, and performance and to monitor how well is the group itself performing. The three biggest GPOs in USA are: Premier, VHA/UHC, and AmeriNet. Out of over 5000 hospitals in the USA, Premier has 1850 hospitals as its members.

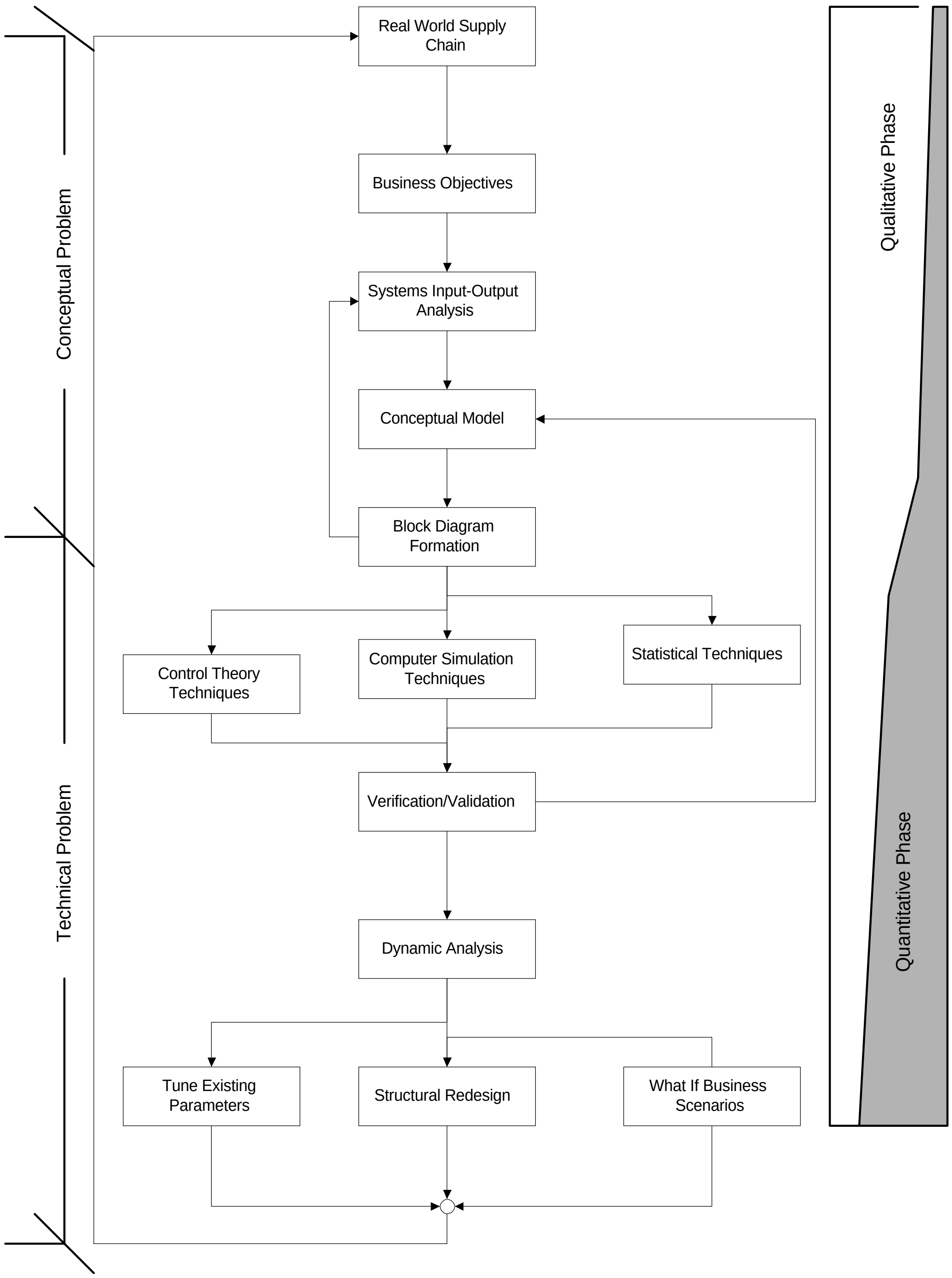

Figure 1: Integrated system dynamics framework for supply chain design. Source: Hafeez et al. (1996)

As mentioned earlier we have used a children hospital from the private health care sector in the USA as a case study. The GPO belonging to this hospital is Premier. The hospital orders its supplies from:

1. Primary and secondary distributors: the hospital orders most of their supplies from one primary distributor (Allegiance), and three other secondary distributors (McKesson, Owens & Minors, and Burgen Brunswick). These distributors have their own warehouses. They provide supplies for several hospitals for an extra charge (about 5%) to distribute the goods according to individual hospital's time and cost constraints. In turn, these distributors order their supplies from product manufacturers (see Figure 2).

2. Product manufacturers: sometimes the children hospital orders its supplies directly from product manufacturers (about 6000 manufacturers).

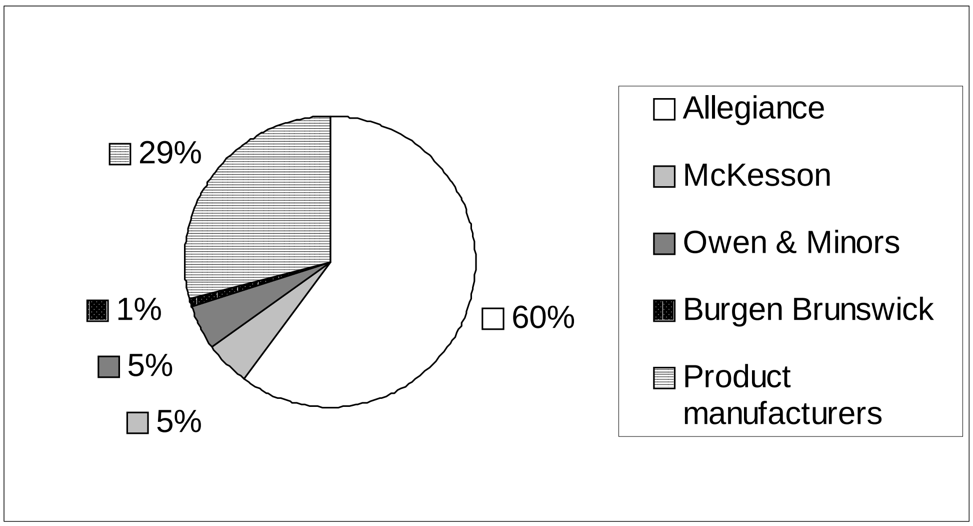

Figure 2: Percentage breakdown of supplier shares for the case hospital.

4.1 System Analysis

Several meetings were conducted with the materials management director of the children hospital to gain sufficient knowledge and understanding of the structure and operation of their supply chain. The hospital supply chain is shown in Figure 3. It includes suppliers, distributors, health service providers and customers who are linked together via the feed forward flow of materials and the feedback flow of information.

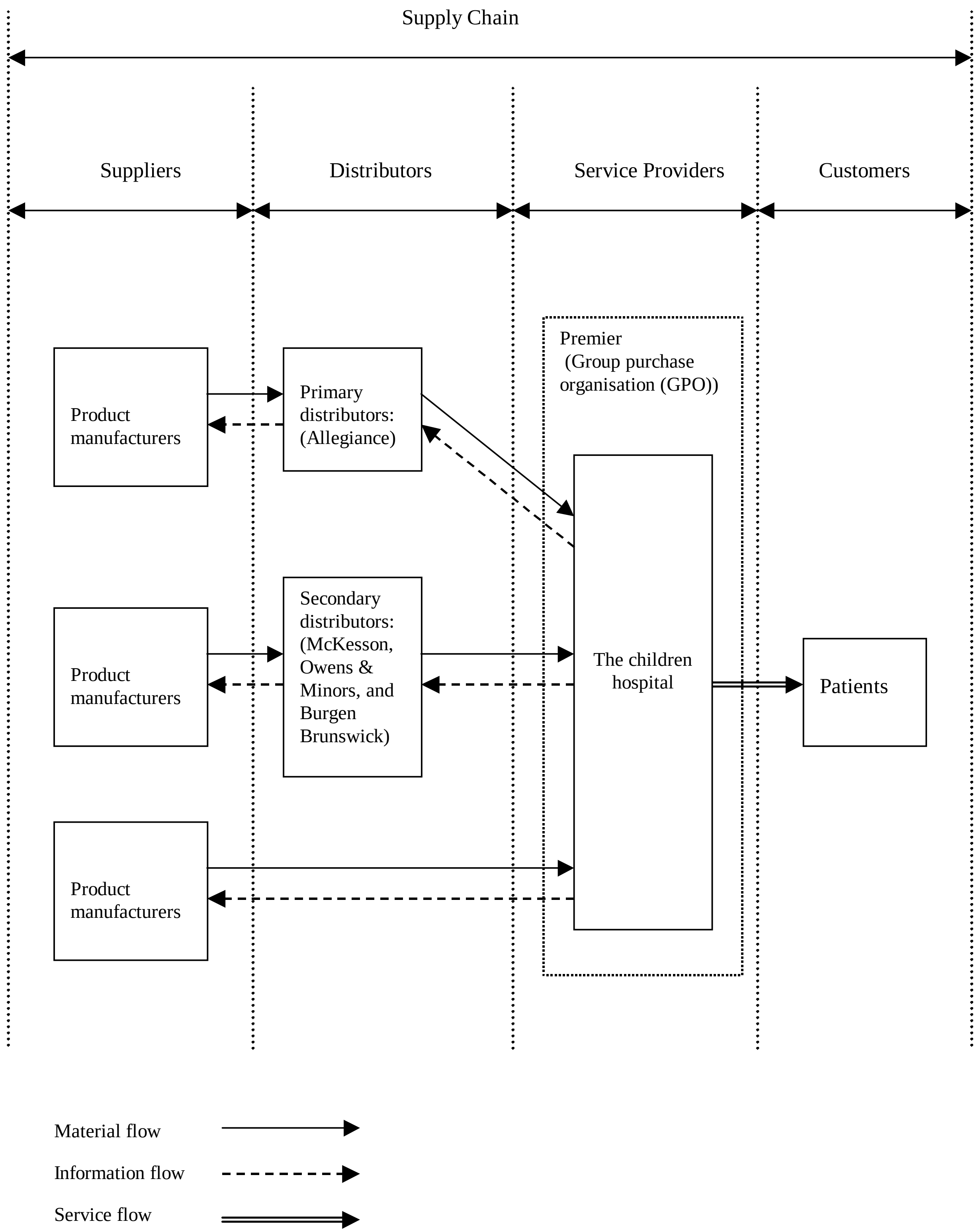

Figure 3: The overall material, information and service flow in the case hospital supply chain.

For the purpose of further analysis, we have used the following two tools:

1. Input-output analysis (IOA) (Parnaby, 1979): IOA helps to identify major systems and the balancing of input and output flows between them (Mason-Jones et al., 1998).
2. Process flow analysis (PFA) (Towill, 1996): PFA allows defining the flow of material through the supply chain and across functional interfaces (Mason-Jones et al., 1998).

As an example, the IOA for the central supply and main warehouse of the hospital are illustrated in Figure 4 and Figure 5, respectively. Individual IOA diagrams as well as PFA diagrams were then all linked together and balanced to develop an overall picture of the cash, materials, information and service flows through the system as described in section 4.2.1.

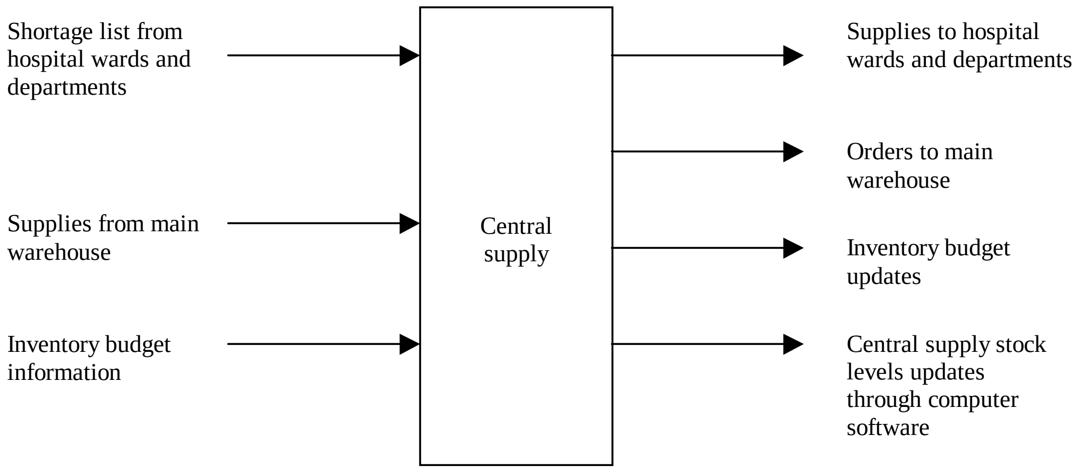

Figure 4: Input-output analysis of the Central Supply.

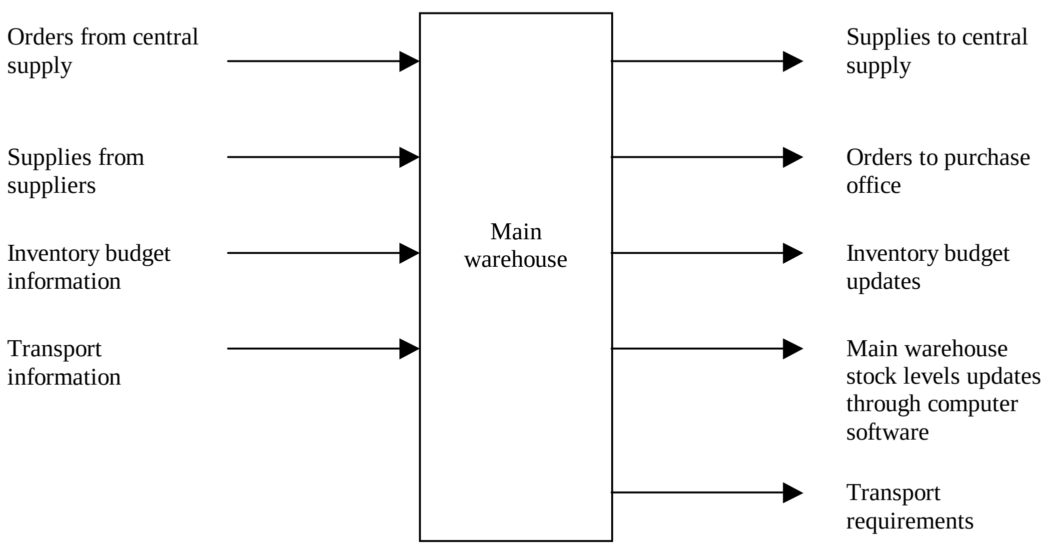

Figure 5: Input-output analysis of the main warehouse.

4.1.1 Inventory management

In most industries, the primary purpose of inventory holdings is to buffer the customer from time lags and offer greater service levels; since having a stock out situation means diverting the customer elsewhere and losing market share (Disney et al., 1997). However, in the health care industry, the customer's health is on the line, and a stock out situation may cost a life. Inventory planning and control attempts to balance the advantages against the disadvantages of holding stock by providing answers to two main questions: when and how much to order (Bonney, 1994). Reisman (1981, pp.1) elaborates these issues as:

> *Clearly, the desired or demanded service levels must be established. Optimizing between costs and service levels requires knowledge of certain analytical techniques in order to develop decision rules for replenishment policies. In addition, it requires an appreciation of simulation techniques to validate and/or pretest such decision rules. Finally, a management infrastructure to maintain and keep all systems in control is essential.*

Classification of items

The items ordered by the materials management department are classified into three types: stock items, non-stock items and special items.

- Stock items (fast moving items): these items are stocked at the main warehouse and represent 98% of all items.
- Non-stock items (slow moving items): these items are delivered directly to the different hospital wards and departments through the hospital receiving dock and they are not stocked at the main warehouse. These items represent about 2% of all items.
- Special items: these are one-time order items.

The classification above is based upon the following criteria:

- If an item is used by the hospital 12 times/year, this is to be stocked at the main warehouse.
- If an item –after being considered as a stock item- is used less than 3 times/year in the following year, it will not be stocked at the main warehouse and will be considered as a non-stock item. Otherwise it will remain considered as a stock item.

Note: A TPR card (Traveling Purchase Requisition Card) is issued for non-stock items. This card has all the requisition information (quantity, requisition date, supplier, …etc.). One of the purposes of this card is to count how many times it is requested by the different hospital wards and departments, and therefore to see if it has to be considered as a stock item or not.

4.1.2 Cash, material, information and service flows for stock items

Figure 6 illustrates the cash, materials, information, and service flows for stock items in hospital logistics system. The different wards and departments consume supplies by importing services to patients. This causes a decrease in the wards' and departments' stocks. The central supply checks the wards' and departments' stock levels every 24 hours. They simply count manually what is on shelves, and fill a prewritten list of all items in stocks. Then they top up these stocks daily to a predetermined level from the central-supply-storage area. The central supply works as an internal distribution system.

The central supply uses special computer software to determine its stocks' levels. When these levels fall below a predetermined level, an order is filled and sent to the main warehouse, which is located one mile away from the hospital. The main warehouse then meets the central-supply demand and checks its stocks' levels on the software system. When the main warehouse levels fall below a predetermined limit, an order is filled and sent to the hospital purchase office. In response, the purchase office sends a purchase order to suppliers (primary distributor, secondary distributors, or product manufacturers), and an electronic copy of the purchase order to the accounts payable office (under the finance department).

Suppliers deliver supplies to the main warehouse receiving dock and send an invoice to the accounts payable office. When the receiving dock at the main warehouse receives supplies from suppliers, they fill a receiving note and send it electronically to the accounts payable office. Then they deliver these supplies to the main warehouse.

The accounts payable office compares and matches the receiving note and invoice with the copy of the purchase order and then sends payments to suppliers. Payments are usually sent 30 days after receiving the invoice from suppliers.

4.1.3 Cash, materials, information and service flows for non-stock items

Figure 7 illustrates cash, materials, information, and service flows for non-stock items through the children hospital logistics system. When any ward or department needs such an item, they send a requisition directly to the hospital purchase office. In turn, the purchase office sends a purchase order to suppliers and a copy of that order electronically to the accounts payable office. Suppliers then deliver the items to the hospital's receiving dock and send an invoice to the accounts payable office.

The hospital's receiving dock delivers the item directly to the ward or department that requested that item and sends electronically a receiving note to the accounts payable office. The accounts payable office, in turn, matches the receiving note and invoice with the purchase order and sends payments to suppliers after 30 days of receiving the invoice from them.

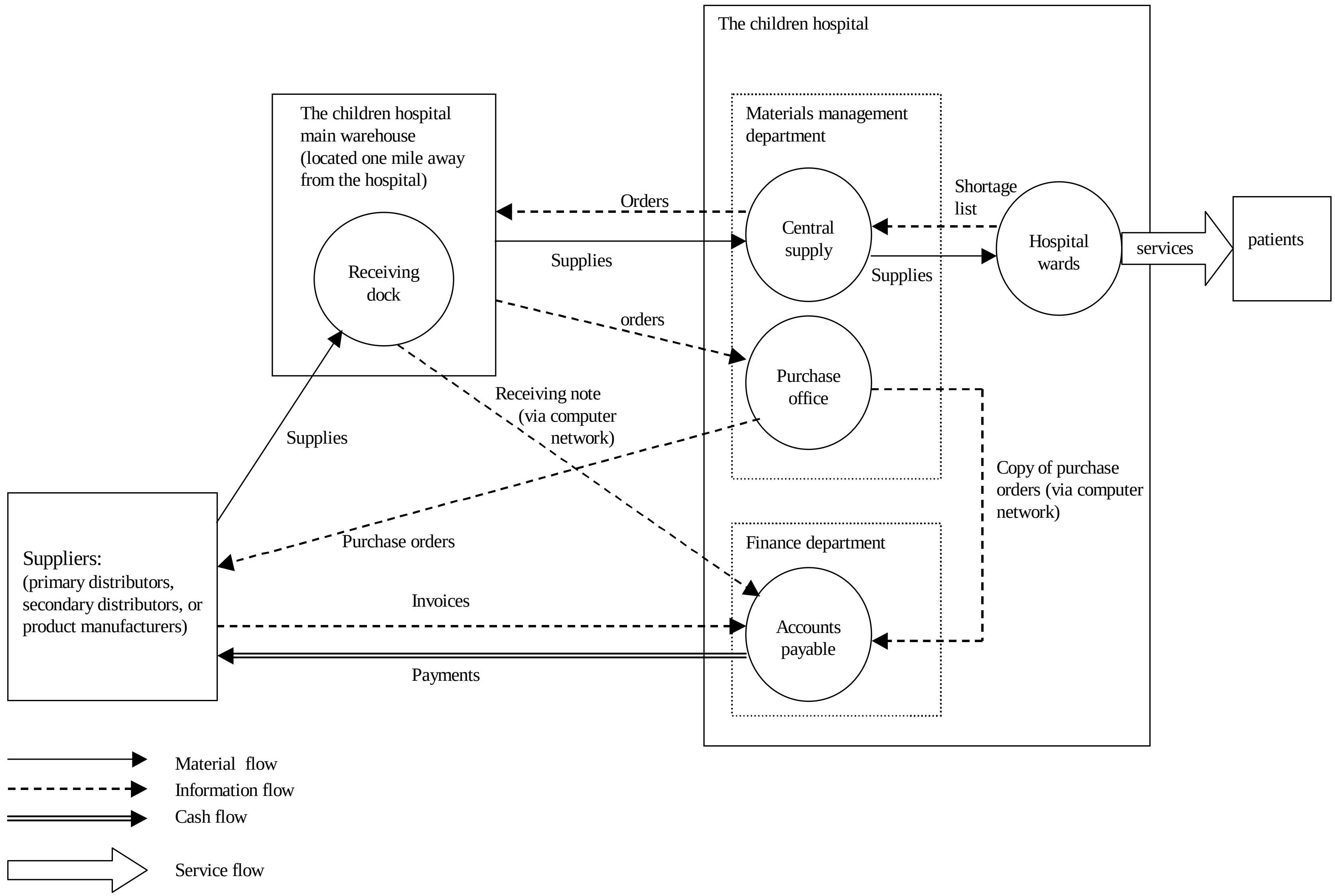

Figure 6: Cash, material, information, and service flows for stock items in the case study.

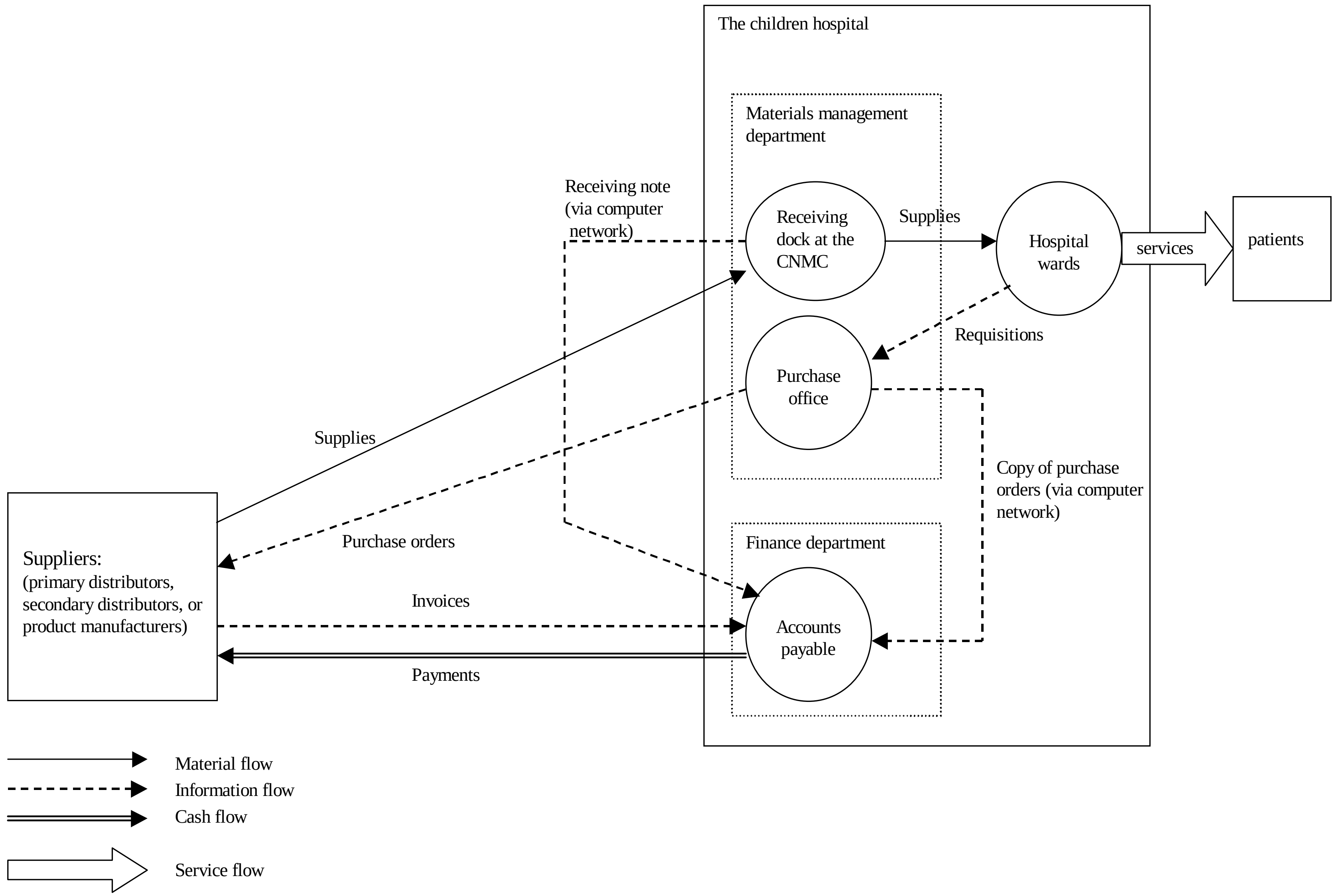

Figure 7: Cash, material, information, and service flows for non-stock items in the case study.

4.2 Main Logistics Activities

Coyle et al. (1996) discussed most of the activities associated with logistics, and listed them in Table 1. Yet, it is not necessary to place responsibility for all of these activities within the logistics area. Haley and Krishnan (1995) argue that a logistics system that focuses on only one particular logistical activity is too restrictive to be very useful. For example, rational management decisions for inventories cannot be made without explicit consideration of interrelations among activities in an overall supply system and with transportation, manufacturing, or other processes (Clark, 1994).

Table 1: Activities associated with logistics. Source: Coyle et al. (1996)

Logistics Activity	
• Traffic and Transportation	• Production planning
• Warehouse and storage	• Purchasing
• Industrial packaging	• Customer service levels
• Materials handling	• Plant and warehouse site location
• Inventory control	• Return goods handling
• Order fulfillment	• Parts and service support
• Demand forecasting	• Salvage and scrap disposal

The following briefly discusses the children hospital main logistics activities that will be taken into consideration when building the conceptual model of their logistics system. The aim of this step is to study how the decision rules related to different logistics activities will affect the system structure (i.e. the cash, materials, information and service flows and their corresponding delays), and then to study in a later step the effect of system structure on system behavior over time.

4.2.1 Approaches used for inventory management

There are three stock levels in the case hospital, namely, ward stocks, central supply (CS) and main warehouse (MWH). A brief description of each is given below:

4.2.1.1 Wards' stocks:

Description of policy: levels of stocks are checked at fixed intervals and sufficient supplies are ordered to top up stocks to a predetermined level.

Fixed order interval = every 24 hours.
Desired inventory level = three day worth of usage, based on 30 days worth of data using standard deviation. This calculation is adjusted depending on how much space is available in the ward's storage area.

4.2.2.2 Central supply and main warehouse stocks:

Economic order quantity (EOQ) approach is used here (Coyle et al., 1996). It involves ordering a fixed amount of product each time reordering takes place. The exact amount of product to be ordered depends upon the product's cost and demand characteristics and upon relevant inventory carrying and reordering costs. The stock ordering level (number of units) depends upon the time it takes to get the new order and upon the product demand rate during that time.

- $EOQ = \sqrt{\frac{2RA}{VW}}$

Where,

EOQ = economic order quantity (units)
R = annual rate of demand for period (units)
A = cost of placing an order ($ per order)
V = value or cost of one unit of inventory ($ per unit)
W = carrying cost per dollar value of inventory per year (% of product value)

Where reorder point: given a known lead time, multiplying lead time by daily demand determines the reorder point.

4.2.2 Purchasing, warehousing and transportation

Purchasing, warehousing and transportation are three separate –yet related- logistics activities. The purchasing activity is the interface between suppliers and their customers. We already illustrated the interaction of the purchase office with other parts of the logistics system (see Figure 6 and Figure 7). Information flow is the only type of flow that comes in and out of the purchase office from and to the other parts. As shown in the figures, purchasing is grouped along with other materiel-oriented functions within a single materials management department. The purpose of this strategy is that by combining material procurement with control, many communications lines (i.e. information flows) are shortened and purchasing policies are likely to achieve greater strategic effectiveness. How effective this strategy is simulated as discussed in the subsequent analysis.

Transportation is concerned with the physical movement and flow of materials between different echelons in the supply chain. Several logistics activities have trade-off relationships with transportation, one of which is warehousing. The decisions related to warehousing including how many warehouses, where to locate the warehouse, what size the warehouse and so on are affected and affects transportation-related decisions such as selecting the mode or modes of transportation used in moving materials or developing private transportation (Coyle et al., 1996).

In this case study, as explained earlier, there are three different storage areas for stock items: wards' stocks, central supply, and main warehouse. Wards' stocks are used for stocking items used frequently when conducting services to patients. The central supply –located at the hospital site- works as an internal distribution system to replenish the deficiencies in the wards' stocks. Whereas, the main warehouse –located one mile away from the hospital- is used to replenish the deficiencies in the central supply stocks. The transport used at the hospital and at the main warehouse- either belongs to the distributor/product manufacturer or to a third party. However, the transportation within the hospital boundary is owned by the hospital itself.

4.3 Conceptual Model

Conceptualization is an important step in the methodology, since the mental model of the system developed during the system analysis stage is made explicit by creating special diagrams (Wolstenholme, 1990). Lane and Oliva (1998) summarise this step as:

> *The problem behavior is identified and described in a reference mode. The factors that appear to be responsible for causing the symptoms are then identified and the relationships between them described. These relationships are framed into information-feedback loops that can be used, in the next phase, to model the system. The relationship between those causal structures and the identified reference mode is called a 'dynamic hypothesis' –a potential explanation of how structure is causing the observed behavior.*

The feedback loops in the model are commonly diagramed using either stock-flow diagrams or causal-loop diagrams (Albin, 1997). These diagrams are alternatively known as pipe diagrams and influence diagrams respectively (Wolstenholme, 1990).

In this case study, the authors have used both diagrams as mediums of conceptualization. Causal-loop diagrams –being simple to understand- were used as a tool to communicate with the materials management director. The verified causal-loop diagram of the hospital logistics supply chain for stock items (shown in Figure 8) is representative of the decision rules related to the different logistics activities as adopted by the materials management department.

4.4 Computer Simulation

The verified causal-loop diagram is subsequently converted into stock-flow diagram as illustrated in Figure 9. We have concentrated on modeling the stock items only as they represent 98% of the total requisition of the case hospital. The authors chose to develop the stock-flow diagram using iThink Analyst. A major feature of the software is that it allows to create stock-flow diagrams directly on the computer screen as icons, which could be opened to insert data to create simulation models, without recourse to separate equation formulation (Wolstenholme, 1998) and (Richmond, 2001). Also the software allows creating mathematical relationships between key variables automatically using the block diagrams.

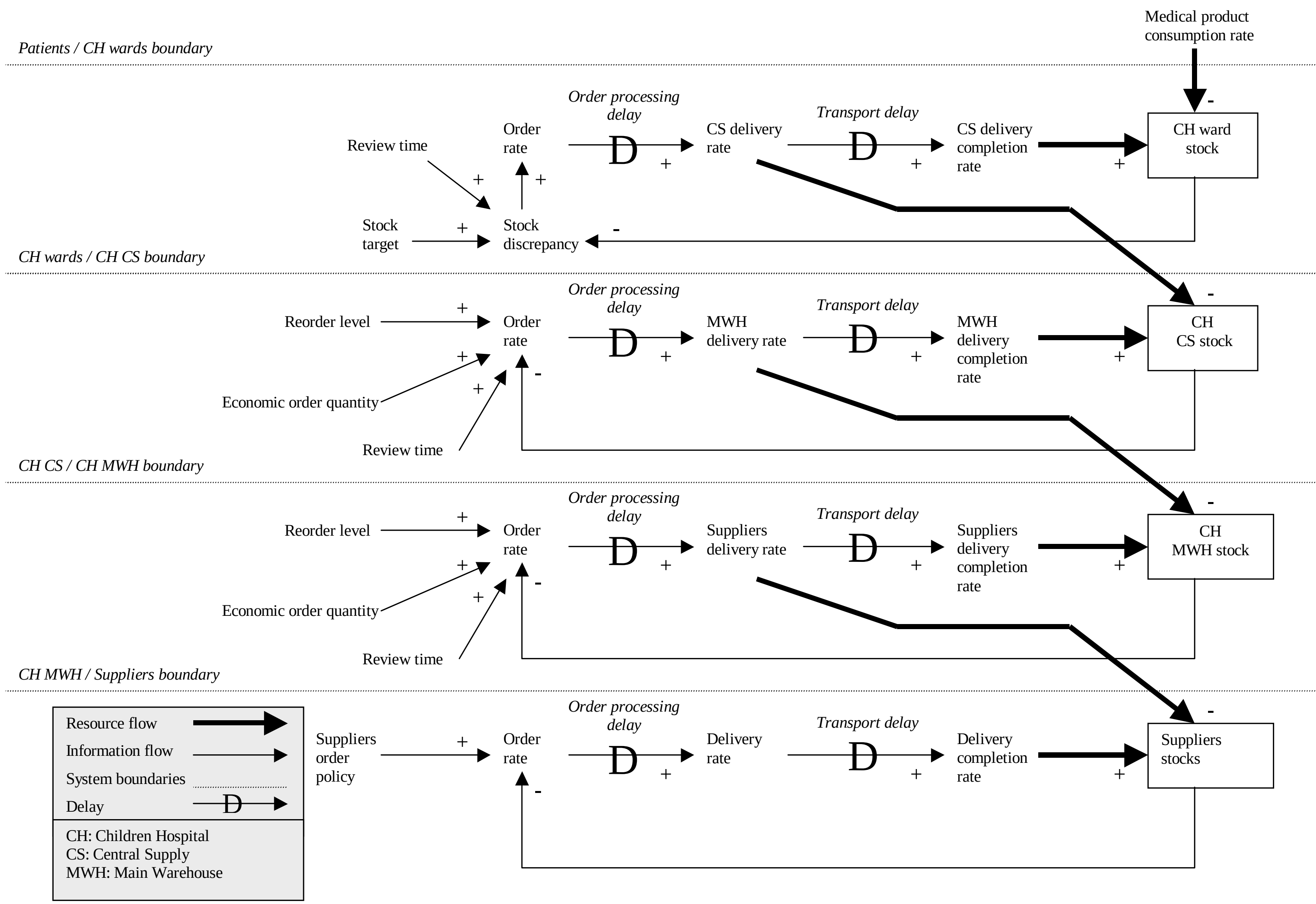

Figure 8: The causal-loop diagram for stock items in the case study.

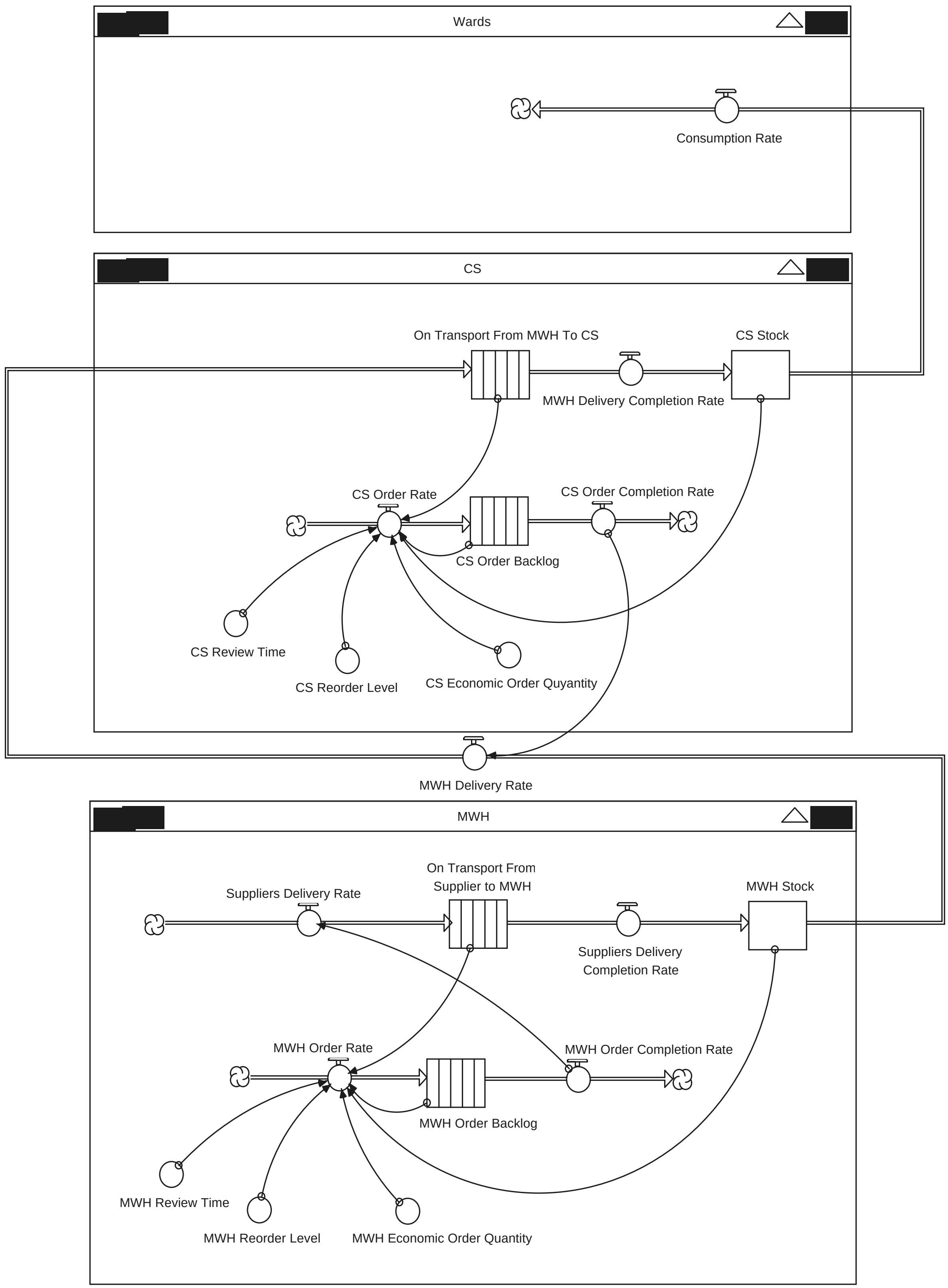

Figure 9: The stock-flow diagram for stock items in the case study.

In the causal-loop diagram, there are four stocks: wards stocks, Central Supply (CS) stock, Main Warehouse (MWH) stock, and suppliers stock. The model in Figure 9 deals with two stocks: CS stock and MWH stock. However, consumption of all wards were summed together and represented in the model as consumption rate. Also, whatever comes from suppliers were represented in the model as suppliers delivery rate.

Both CS and MWH stocks model represent a traditional EOQ inventory replenishment model of the periodic review type. Inventory drops at a rate given by demand as a function of time and is replenished in batches after a certain lead time, when its level reaches or has fallen below a reorder point, represent the trigger level. The following principle assumptions usually are taken into consideration in a simple EOQ model (Coyle et al., 1996):

- A continuous, constant, and known demand rate.
- A constant and known replenishment or lead time.
- The satisfaction of all demand.
- A constant price or cost that is independent of the order quantity or time.
- No inventory in transit.
- One item of inventory or no interaction between items.
- Infinite planning horizon.
- No limit on capital availability.

The data needed to run the model in Figure 9 are: wards consumption rate, CS and MWH order delays, CS and MWH transport delays, CS and MWH inventory management policies (i.e. economic order quantity (EOQ), reorder level (ROL), and the number of time units elapsing between reviewing the inventory position). Part of the data was available from the hospital in our case. The rest of the data were calculated according to the hospital decision rules. Data about actual stocks level was not available. Therefore, the authors could not validate the model against field data and see whether the model can accurately reproduce past statistical data as observed in the real system. However, Wolstenholme (1990) argues that in system dynamics models validity is seen as a more complex concept that centers on user confidence in the model. He adds that this confidence stems from an appreciation of the structure of the model, its general behavior characteristics and its ability to generate accepted responses to set policy changes. To gain this confidence, the authors conducted several tests suggested by Wolstenholme (1990), which he had adapted from Sterman (1984).

The model in Figure 9 was run for different items. As an example, we have used a stock item Scalpel sterile disposable supplied by Allegiance - a primary distributor, in our simulation. A demand pattern of this item is given in Table 2.

Table 2: Summary of demand pattern for the item used in simulation

Item description	Scalpel sterile disposable 11
Item number	16205
Month/Year	**Demand**
6/98	80
7/98	166
8/98	307
9/98	95
10/98	72
11/98	129
12/98	79
1/99	73
2/99	52
3/99	106
4/99	280
5/99	133
Average monthly demand	131
Desired Quantity	41.04
Base price	$ 0.7189

The required data to run the simulation model for the above item was calculated using standard procedures and given in Appendix 1.

4.5 Dynamic Analysis

Figure 10 shows the dynamic behavior of consumption and CS stock level over time. The consumption rate varies over a month. Therefore, CS stock depletes gradually till it reaches the reorder level. After a time (equals to CS lead time) the CS stock is replenished by an amount equals to EOQ. The dynamic behavior of CS stock level resembles the behavior of an EOQ model under conditions of uncertainty, where the slope of the sawtooth varies for each order-cycle depending on the consumption rate during that cycle.

Figure 11 shows the dynamic behavior of MWH delivery and MWH stock level over time. The MWH delivery rate is the consumption rate of the MWH stock. As shown the MWH delivery rate is represented as a pulse function (with a magnitude = EOQ/dt) generated by the ordering process. The function represents the order rate and delivery rate for different batches (=EOQ) at certain points in time. Therefore, MWH stock level decreases abruptly in an amount equals to EOQ at each pulse of the MWH delivery rate. For this reason, the dynamic behavior of MWH stock level represents a square wave rather a typical sawtooth pattern representative of an EOQ model.

This may lead to a stockout situation (i.e. if MWH stock level is less than or equals (n EOQ), and the time between (n) successive pulses of MWH delivery rate is less than the MWH lead time. Threfore stockout situation may be experienced first at the MWH stock and subsequently at the CS stock.

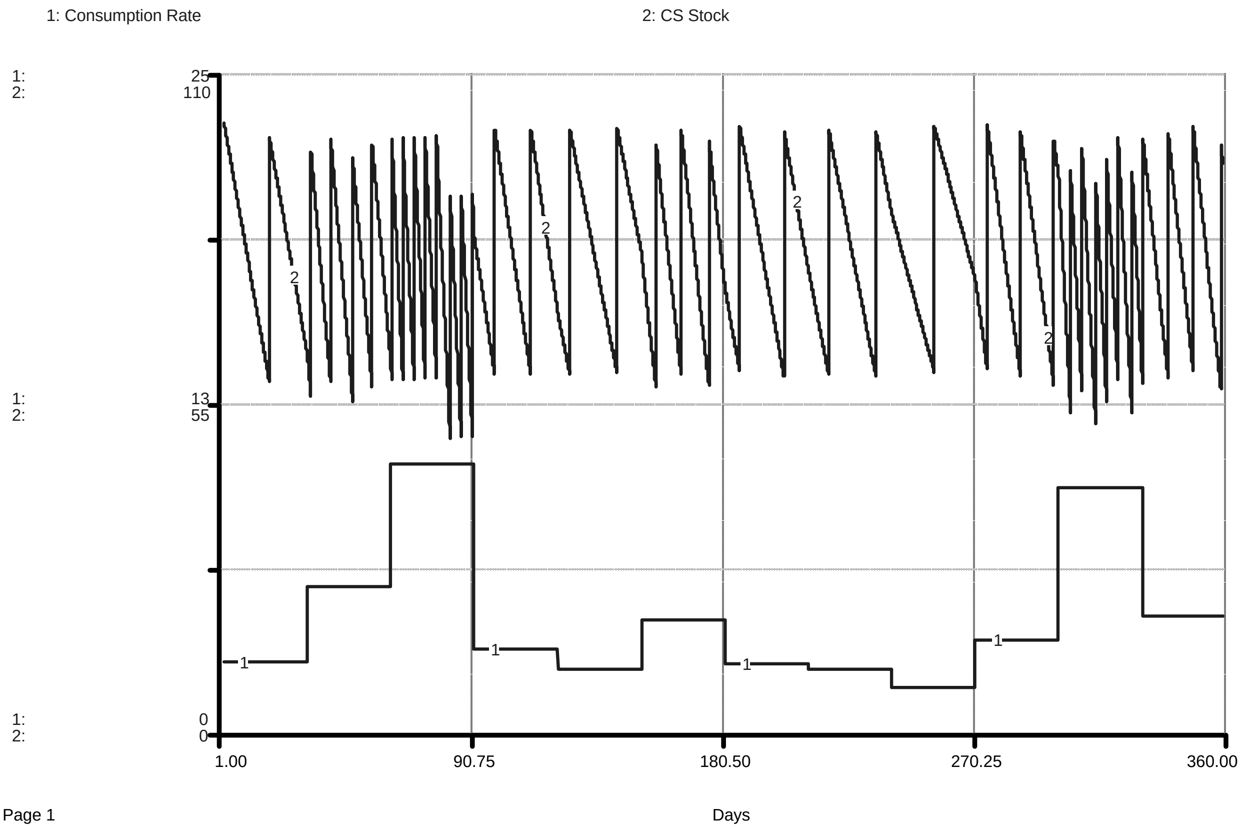

Figure 10: The dynamic behavior of consumption and CS stock level over time.

The hospital keeps two weeks worth of safety stocks both for CS and MWH as a protection against the uncertainties of unexpected changes in demand and an interruption in the rate of supply. For CS the supply lead-time is small and very reliable (order delay and transport delay are within the hospital control). Therefore, the only justification for the high safety stock level is the protection against unexpected high demand. Yet, in case there is unexpected high demand, which causes a stockout in CS stock, at worst cases this stockout will not be more than one day – assuming there is no stockout or possibility of stockout in MWH stock.

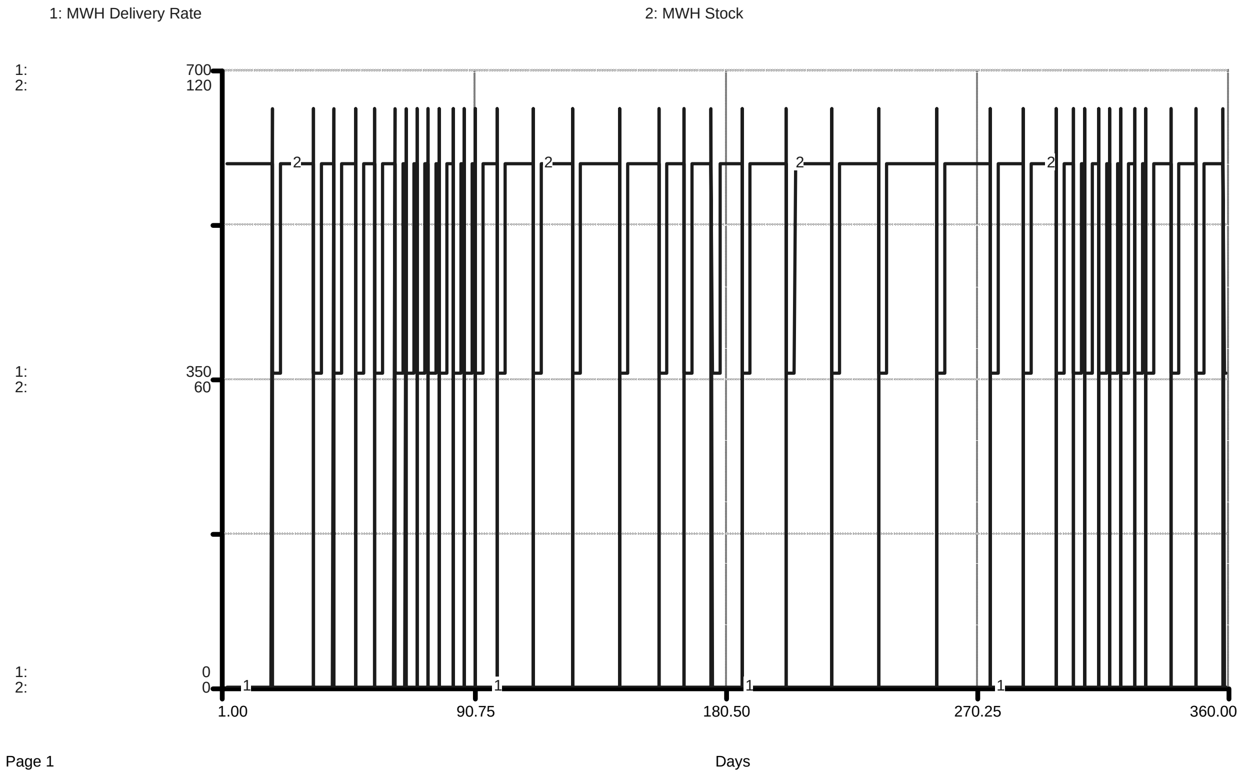

Figure 11: The dynamic behavior of MWH delivery and MWH stock level over time.

In overall, it was concluded that the existing inventory control policies that are based on trigger rules (i.e. a replenishment for a batch is generated as soon as a trigger level is reached), were the cause of the following undesirable conditions:

- Excessive fluctuation in stocks level (i.e. the typical sawtooth pattern generated by this type of traditional inventory control policies).
- The order policies employed are non-linear (Grubbström & Wikner, 1996), generating a sequence of order impulses rather than the continuous-time order flows modeled by linear policies.
- Holding high stocks levels, which was also emphasized by the Materials Management Director of the case hospital to be one of the drawbacks of an EOQ model –especially for slow moving items.

The authors also found that the typical inventory control policies –which typically combines elements of both the pull and push philosophies (Coyle et al., 1996)- are not suitable for the type of demand which usually health care systems are characterized by. As mentioned earlier at the beginning of this paper, health care organizations have very little control over demand for supplies. Therefore, it is suggested to shift the hospital logistics strategy from a supply-side push orientation to a demand-side pull orientation.

5 Conclusions

This paper describes the analysis and modeling of an American health care provider logistics supply chain using an integrated system dynamics framework. Based on the system analyses, causal relationships were developed and a computer simulation model was built. The simulation model was tested on a moderately fluctuating stock item. The simulation analysis reveals that some inventory control policies that are based on trigger rules were causing the following undesirable characteristics: excessive fluctuation in stocks level, holding high stocks level, and employing non-linear ordering policies. Moreover, it was found that the existing "push" type inventory control policies are not suitable for the type of demand that is usually experienced by the health care systems. The authors further suggest that items should be ranked in terms of **value** and **criticality** rather **frequency of use** to develop appropriate stocking policy. This would allow choosing suitable level of safety stock to minimize stockouts where it is cost effective to do so, and avoid stockouts only on essential and critical items.

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Appendix1: The data to run the simulation model for the Scalpel sterile disposable item (from Table 2)

- The total monthly demand was averaged to get the average daily demand for that month for the purpose of using it in the model, which was entered in the model as a graphical function (i.e. consumption rate for certain month = average daily demand in that month).

- The initial value of CS stock and MWH stock = EOQ + Safety stock
  = 41 + 61 = 102
  where safety stock = two weeks stock
  = (2) (7) (average monthly demand/30)
  = (2) (7) (131/30) = 61

- The time it takes CS to order the item from MWH and receive it = about 6 hours which was divided as 3 hours ordering delay and 3 hours transporting delay.

- The time it takes MWH to order the item from Allegiance (their supplier for that item) and receive it = 48 hours, which was divided as 24 hours ordering delay and 24 hours transport delay.

- Reorder level = [(lead time) (average monthly demand/30)]+ (safety stock)
  for CS: ROL = [(.25) (131/30)] +61 = 62 (where 0.25 = 6 hours)
  for MWH: ROL = (2) (131/30) +61 = 70

- The report shows a desired quantity for the item = 41.04. The authors assumed that this value is the value of the EOQ since the hospital calculates resupply for CS and MWH based on economic order quantity EOQ. The hospital did not show us how they calculated this value. No data were given to us about ordering cost and inventory cost.

- Two counters were used in the model: CS Review Time and MWH Review Time. They represent the number of time units elapsing between reviewing the stock level for CS and MWH respectively. For both CS and MWH inspection is done every 24 hours.

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