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An Integrated Approach for Improving Logistics Systems: A Case Study of Hospital Logistics

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***Abstract* – In order to provide an integrated approach to improve healthcare logistics. This paper integrated the analysis of logistics decisions made at the three hierarchical levels with the problem analysis and improvement suggestions. Following a thorough analysis of the problematic logistics decisions, alternative decisions were suggested to improve the current logistics system. The proposed forecasting technique is expected to reduce the average error in forecasting as a percent of average demand from 30.3% to 22.5%. The proposed methodology provides a new structured problem-analysis and problem-solving processes for healthcare logistics and it is expected to be a valuable management tool to improve the quality of patient care.**

***Keywords* – hospital logistics, process improvement, hierarchical logistics decisions, strategic planning level, network design level.**

1. Introduction

Recently, healthcare providers are paying more attention to hospital logistics.

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As in industrial applications, hospital logistics are now seen as potential areas for improvement and increased efficiency without affecting patients' safety and care [1]. Improving logistics can lead to reduction in logistics cost, reduction in time and delays, improvement in supplier relations, improvement in reliability, and improvement in flexibility [2], [3], [4], [5]. Hospitals are known to have a material-centered external logistics and a patient-centered internal logistics [6], [7], [8]. Internal logistics refers to the flow of material within the hospital itself.

The logistics decisions made at the three hierarchical levels are the ones that determine how the logistics system works and accordingly how the system performs. These levels are the strategic planning level, network design level and operational level. Riopel et al. [9] highlighted the differences between each of the three levels as summarized in Table 1. Although the logistics culture is not fully integrated within the strategic level of hospitals [10], the awareness about the strategic level decisions in relation to the logistics system is increasing [11]. In literature, several studies focused on improving logistics using different approaches like: Six Sigma DMAIC framework [12], [13], [14], [15], Plan-Do-Check-Act (PDCA) cycle [16], [17], Business Process Reengineering (BPR) methodology [18], [19], and KAIZEN [20], [21]. In most of these studies, the focus was on determining the problems and their causes without relating them to the logistics decisions taken at the three hierarchal levels. Moreover, in most cases, there is lack of information about logistics decisions. Usually, this type of information is either in the minds of people taking the decisions or documented partially and separately. To improve the system, it is necessary to know how the decisions interact to impact the performance. The main contribution of this research work is to integrate the analysis of decisions made at the three hierarchical levels with the problem analysis and improvement suggestions.

Table 1. Differences between the three hierarchical levels [9]

Hierarchical level	Management level involved	Time horizon	Comments
Strategic Planning	High	Long term	- Often align with the organization's strategy and goals - Affect functional areas beyond logistics functions
Network design	Intermediate	Between long term and short term	- Translates the strategic level decisions into structural ones - Requires expenditures to be executed
Operational	Low	Short term	- Decisions taken repetitively - Highly interchangeable

This paper is organized as follows. Section 2 describes the research methodology. Whereas Section 3 presents the case study of this research work including the analysis and improvement technique. The last section concludes the main findings of this research work.

2. Methods

The research methodology applied to the case study hospital was approved by the institutional review board. The research methodology is illustrated in Figure 1. The improvement process proceeds through several major steps which are: define logistics problems, analyze logistics problems, and solve logistics problems. These are the same steps followed in any problem-solving process. However, the uniqueness of our methodology is to integrate the analysis of the logistics decisions made at the three hierarchical levels with the problem analysis and improvement suggestions. First, a thorough analysis of the current logistics decisions is done for each of the three hierarchical levels: strategic planning level, network design level and operational level. The information generated from the analysis is saved in a computerized information system developed for this purpose. This information is then retrieved during the problem analysis process to study how the logistics decisions at the three hierarchical levels interact and impact the problem under study. Moreover, the improvements taken to solve the logistics problems are done through suggesting new logistics decisions to be implemented at one or more of the hierarchical levels. The newly suggested logistics decisions are expected to help in achieving a better performance and further improvements on the problematic areas. The computerized information system is then updated to be used again in analyzing future problems.

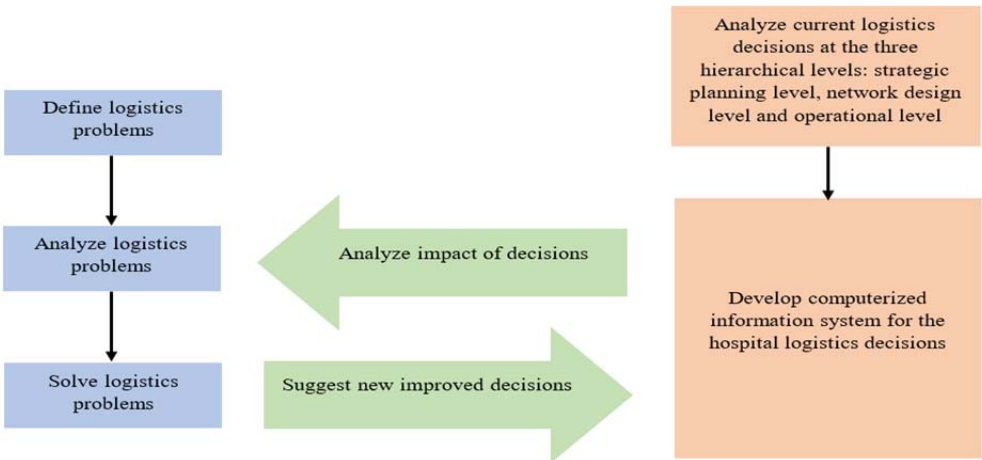

Figure 1. Methodology of research

3. Results

The case study for this research work is a general hospital from the public sector in Jordan. An improvement initiative was taken to improve the inbound logistics of the hospital. The hospital's inbound logistics system includes six main activities, namely: demand forecasting, inventory management, warehousing, order processing and material handling. The main problem in the case hospital logistics system was defined as the multiple occurrences of overstocking and out of stock situations for different stock keeping units (SKUs). Stock-outs in hospitals reduce patient satisfaction and can put patients' lives at risk, especially if critical items are missing [22]. Whereas, overstocking ties up the organization capital for extended periods of time [23]. Instead of beginning with using the familiar tools to analyze the main causes of the problem (e.g. cause and effect diagram, Pareto chart, five whys, scatter diagram), a thorough analysis of the hospital logistics decisions at the three hierarchical levels are done first. The main aim is to link the problem with the decision/s that are suspected the most to have a direct impact on it.

3.1. Analysis of the Logistics Decisions

Riopel et al. [9] defined a set of decisions within each of the strategic planning level, network design level and operational level. These sets were used as a guidance to determine the current logistics decisions taken at the case hospital for the three hierarchical level. Several site visits to the case hospital were made to understand and determine the current strategic, network and operational level decisions. Interviews were conducted with the personnel involved in each level of the decisions. The decisions that have been analyzed are summarized in Table 2.

Table 2. Logistics decisions at the three hierarchical levels

Hierarchical level	Sub-level	Decisions
Strategic Planning Level		Definition of customer service Customer service objectives Degree of vertical integration and outsourcing
Network-Design Level	Physical Facility (PF) Network	PF network strategy PF network design, including: -Types of facility -Number of each type of facility -Size of facility -Facility location -Activities and services from each facility -Utilization of new or existing facilities -Links between facilities
	Communication and Information (C&I) Network	C&I network strategy C&I network design including: -Network architecture and capacities -Hardware selection -Software selection -Vendor Selection -Extent of information and technology used
Operational Level	Demand Forecasting	Forecasts of demand magnitude, timing and locations
	Inventory Management	Inventory management strategy Relative importance of inventory Control methods Desired inventory level Safety stock
	Procurement and supply management	Procurement type Specifications of good procured Suppliers Order intervals and quantities Quality control
	Material Handling	Unit loads Types of material handling equipment Material handling fleet mix
	Warehousing	Warehousing mission and functions Warehouse layout Stock location Receiving/shipping dock design Safety systems
	Order Processing	Order entry procedures Order transmission means Order picking procedures Order follow-up procedures

3.2. Linking Problem with the Problematic Decisions

After conducting a brainstorming session with the management team and people of concern, the main problem was linked directly to the following decisions:

1- Strategic planning level:

- *Definition of customer service*: Regarding the logistics system, there is no current definition for customer service that is related to logistics. Moreover, there are no metrics set for measuring customer service in relation to logistics. So, since there are no measures for the out of stock and overstocking percentage or amount of occurrence through the year, the problem cannot be quantified especially in financial terms. Not monitoring these situations reduces the awareness on the importance of avoiding them to achieve better customer services.
- *Customer service objectives*: There are no customer service performance standards currently set for hospital's logistics system. Not setting target values for the out of stock and overstocking situations and working on reducing the gap between the actual values and the desired values might have contributed to reducing the chances for improvement. Moreover, if such target values were not set, the problem might get bigger gradually.

2- Network-design level:

- *Extent of information technology used*: At the case study of hospital, the inventory management electronic system provides multiple sets of data regarding the inventory management and procurement values. This includes the daily, weekly and annual demand for all SKUs stored. The annual demand data is used as a reference to judgmentally forecast the annual needs of the next year. However, the information system does not conduct any further analysis regarding forecasting future demand. If the system supports different forecasting techniques, a range of forecasted quantities could be given to experts instead of determining them judgmentally.

3- Operational level:

- *Forecasts of demand magnitude*: The method used by the case hospital to forecast the demand of SKUs in main warehouses is mainly judgmental based on experience and previous demand. This led the decision makers to take incorrect decisions regarding the quantities to be ordered. This, in turn, caused the occurrences of overstocking and out of stock situations.

According to the hospital's management and concerned people, the "forecasts of demand magnitude" is considered to be the main problematic decision that contributes the most to the problem. Accordingly, the current forecasting decision taken at the case hospital was further analyzed and investigated as discussed in the following subsection.

3.3. Analysis of the Problematic Decisions

The 311 SKUs stored in the general medical consumables (GMC) main warehouse were chosen for analyzing the current forecasting method implemented at the hospital. The data needed for the analysis was obtained from the IT department. Data was extracted from the inventory management electronic system. The obtained data included the name, code, type, and actual annual demand for all selected SKUs.

The annual demand for the years 2016 to 2019 was obtained for all 311 SKUs. According to the demand pattern, SKUs were categorized as new, previously ordered and end. The new SKUs are items ordered for the first time in the year 2018 or 2019 with no history of previous demand. Previously ordered SKUs are items that showed demand during the last 4 years. End SKUs are items that had zero demand for the last 2 years. Furthermore, previously ordered SKUs were categorized into two types: intermittent demand and regular demand. The intermittent demand is the demand that fell to zero level in one year or even more in the last 4 years. While, the regular demand is the demand that continued to have a value above zero for the last 4 years. Table 3 shows the number of SKUs for each category.

Table 3. Categories of SKUs

Category	Number of SKUs
Previously ordered/ regular demand	209
Previously ordered/ intermittent demand	63
New in 2018	21
New in 2019	16
End	2

To analyze the current forecasting method, the forecast error was calculated for the 272 "previously ordered" SKUs using Eq. (1). The data about forecasted annual demand was extracted manually from purchasing orders. Again, this lack of information is caused by the poorly implemented decision of "*Extent of information technology used*" explained earlier in the previous subsection.

$$E_t = D_t - F_t \qquad (1)$$

Where

E_t: Forecast error
D_t: Demand for year t
F_t: Forecasted demand for year t

The Mean Absolute Deviation (MAD) was chosen as a measure to evaluate the forecasting method used. The Mean Absolute Percent Error (MAPE) could not be used to evaluate the forecasting method since the demand is intermittent for some of the SKUs. The MAD is calculated using Eq. (2). The average MAD of all SKUs for the current forecasting technique is 13266.3 items.

$$MAD = \sum \frac{E_t}{n} \quad (2)$$

Where

$|E_t|$: The absolute value of the forecast error
n: Number of forecasted years

Several forecasting techniques were proposed to forecast the annual demand of the 272 "previously ordered" SKUs. Table 4 summarizes the equations of the proposed forecasting techniques.

Table 4. Proposed forecasting techniques

Forecasting technique	Equation
Simple moving average	$F_{t+1}=\frac{D_t+D_{t-1}}{2}$ (3)
Weighted moving average	$F_{t+1}=w_1\times D_t+w_2\times D_{t-1}$ (4)
Exponential smoothing	$F_{t+1}=\alpha\times D_t+(\alpha-1)F_t$ (5)
Naïve	$F_{t+1}=D_t$ (6)

Where

F_{t+1}: Forecasted demand for year t+1
D_t: Demand for year t
D_{t-1}: Demand for year t-1
w_1: Weight for year t
w_2: Weight for year t-1
α: smoothing parameter
F_t: Forecast demand for year t

The proposed forecasting techniques were used for the "previously ordered" SKUs with regular demand separately from the "previously ordered" SKUs with intermittent demand. Table 5 shows the average MAD of all SKUs and its value as a percent of average demand of all SKUs for each forecasting technique.

Table 5. Comparison between forecasting techniques based on average MAD for each demand type

Demand type	Forecasting technique	Average MAD of all SKUs	Average MAD as a percent of average demand of all SKUs
Regular	Simple moving average	13475.9	22.9%
	Weighted moving average (w_1=0.7, w_2=0.3)	11651.9	19.7%
	Weighted moving average (w_1=0.8, w_2=0.2)	10945.8	18.6%
	Exponential smoothing (α=0.9)	10473.5	17.8%
	Exponential smoothing (α=0.7)	12362.1	21%
	Exponential smoothing (α=0.3)	19741.7	33.3%
	Naïve	9998	17%
Intermittent	Simple moving average	52111.8	100%
	Weighted moving average (w_1=0.7, w_2=0.3)	47237.1	90.6%
	Weighted moving average (w_1=0.8, w_2=0.2)	44805.2	86.1%
	Exponential smoothing (α=0.9)	42178.7	81.1%
	Exponential smoothing (α=0.7)	45436.6	87.3%
	Exponential smoothing (α=0.3)	47275.8	91%
	Naïve	39953.8	76.9%

For the 209 regular demand SKUs, the naïve forecasting method is the best one with the lowest MAD that equals 17% of average demand of all SKUs. Whereas, for the 63 intermittent demand SKUs, all forecasting techniques give high values of average MAD. This is expected because the nature of the intermittent demand makes the forecasting much harder since the demand reaches zero level in one or more of the years. However, the naïve forecasting technique also gives the lowest average MAD.

3.4. Suggest New Improved Decisions

Based on the analysis of current problematic decisions, several new logistics decisions were suggested to be implemented at the three hierarchical levels as follows:

1- Strategic Planning level:

- *Definition of customer service*: It is recommended to rephrase the customer service definition to include a statement regarding the availability of necessary materials for patient service.
- *Customer service objectives*: It is recommended to set metrics for measuring customer service in relation to logistics (e.g. number of stock-out incidents, number of expired holding items). Moreover, it is recommended to set a target for the chosen metrics and conduct continuous monitoring of the gap between the actual values and the target.

2- Network-design level:

- *Extent of information technology used*: It is recommended that the inventory management electronic system be supported with different forecasting tools that can be used by decision makers to take better decisions regarding future SKUs demand.

3- Operational level:

- *Forecasts of demand magnitude*: It is recommended to use the naïve approach to forecast the demand of regular demand SKUs. However, the naïve approach is considered a bit risky for the intermittent demand SKUs since it might forecast the demand equal to zero based on the previous year. This will affect the quantities ordered for the next year. Therefore, the exponential smoothing (with α =0.9) which is the second-best technique is recommended to be used to forecast the demand of intermittent demand SKUs.

3.5. Evaluating the Proposed Forecasting Techniques

The combination of the two proposed forecasting techniques were evaluated in comparison with the current one. Table 6 summarizes the comparison between current and proposed forecasting techniques in terms of the average MAD of all SKUs and its value as a percent of average demand of all SKUs. The proposed forecasting techniques reduced the average error in forecasting as a percent of average demand from 30.3% to 22.5%. This reduction in forecast error will improve the decisions regarding the amounts ordered at the beginning of each year. This, in turn, will reduce the occurrences of overstocking and out of stock incidents.

Table 6. Comparison between current and proposed forecasting techniques

Forecasting Technique	Average MAD of all SKUs	Average MAD as a percent of average demand of all SKUs
Current	13266.3	30.3%
Proposed	9872.5	22.5%

4. Discussion and Conclusion

Failing to address all logistics decisions at the three hierarchical levels and how they contribute in causing problems in healthcare logistics might reduce the chances to solve these problems and achieve a better performance. The hierarchical levels include strategic planning level, network design level and operational level. The proposed methodology in this paper provides the following benefits:

- It provides a structured problem-analysis process
- It reduces the time lost in debate about the causes of the problem
- It identifies all decisions that have direct impact on the problem
- It provides a structured problem-solving process which ensures sustainable improvements

In this paper, the integrated approach for improving logistics systems is used to solve the problem of overstocking and stockout situations at a case study hospital. The main problem was linked directly to several logistics decisions. At the strategic planning level, customer service definition is not set-in relation to logistics and hence no customer service objectives are set for the hospital’s logistics system. At the network design level, the inventory management electronic system of the hospital does not support demand forecasting techniques. While at the operational level, forecasting demand is done judgmentally which leads to incorrect decisions regarding ordered quantities. The improvement of the system was conducted through proposing new logistics decisions. In this paper, we presented how the integrated approach can be used effectively to deal with healthcare logistics problems. Our findings showed that the proposed forecasting technique is expected to reduce the average error in forecasting as a percent of average demand from 30.3% to 22.5%. Moreover, implementing the proposed logistics decisions altogether at the three hierarchical levels are anticipated to boost the performance of the whole logistics system. The case study is representative and can be generalized in terms of the applicability of the proposed framework in healthcare logistics. The results of this study provide guidelines for hospital logistics managers to integrate the analysis of logistics decisions with process improvement to improve healthcare logistics.

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