MANAGEMENT OF HOSPITAL SUPPLY CHAIN: NEW METHODOLOGY FOR IMPROVING THE PERFORMANCE OF THE MAINTENANCE OF MEDICAL DEVICES

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ABSTRACT
This paper is directed towards a study of the impact of grouping of pharmacies in the hospital supply chain performance for the maintenance of medical devices. The first part of the article shows the interest of the hospital logistics and the literature on the evaluation of performance. The second part describes the steps of our methodology. We finish our work by applying our approach to a hospital in Morocco.

Keywords: hospital logistics, maintenance, performance indicators, grouping, security, quality, nomenclature.

INTRODUCTION
Today, Moroccan hospitals are under pressure from budgetary restrictions, accreditation obligations and guardianships, so they need to develop new management tools and decision support to better manage their business with increased budgetary limitations pressure [1] [2] [3] [4]. Hospital supply chain and its impact on the performance of health facilities are well recognized [5] [6] Thus hospital performance evaluation is now considered a key factor of the quality of care improvement process [7] [8] [9]. The problem of choosing a better approach to organizational performance measurement of hospital supply chain was raised by a lot of hospital managers. The grouping of pharmacies (Medicines and Medical Devices) allows the hospital to pool resources and master inventory, reduce waste and provide better centralized inventory management with visible traceability [10].

Currently hospital managers know that medical devices affect directly human life. They require considerable investments and often have high maintenance costs. It is therefore essential to have a corrective and preventive maintenance strategy capable of ensuring health care, reliability, security and availability of medical equipment. It is in this context that we suggest a methodology for the study of the organizational impact of hospital supply chain on the budgetary performance of medical devices maintenance in the case of grouping pharmacies.

INTEREST OF THE STUDY
Definitions
Hospital logistics are defined as a complex function that manages the flow of products and different distribution channels ([11] [12]). In our article, we retain the definition of logistics as "patient satisfaction requirements (products or services) through an optimization of the various functions of the hospital."

Figure-1 illustrates hospital logistics chain and highlights its key players and their characteristics:

Interest of logistics and pharmacies in health facilities
Several experts considered the importance of logistics costs in health institutions assessments. Housley’s estimate is 46% for North American hospitals [13]. According to Henning, evaluating hospital logistics takes 42% of a hospital’s total expenditure [14] the experts estimate is 46% [15]. This important part of logistics costs shows that logistical procedures in hospitals have become important vectors of health expenditure reduction process. The pharmacy occupies an essential role in the operation of a health facility. It is not directly involved in the act of care, but the pharmacy is mostly involved in many activities that contribute to the successful implementation of this act [16]. It presents the intersection of the flow of pharmaceutical products (medicines, medical devices). According to Delomenie, this service represents nearly
15% of the hospital budget [17]. Thus Di Martinelly hospital pharmacy represents a significant share of the expenses of a health facility [18].

**Importance of the maintenance function in health facilities**

Maintenance of medical equipment can be divided into two broad categories: preventive maintenance (PM) and corrective maintenance (CM) (World Health Organization, 2012). In the health sector, the good management of maintenance is an essential element for the effectiveness of care services. Health technologies are essential to the functioning of a health system. Medical devices in particular are essential for the prevention, diagnosis and treatment of disease and monitoring of patients. The issue of maintenance is to exploit the available resources (human, material) to ensure quality service in the operation of medical devices, taking into account the requirements of users and the service satisfaction level. To optimize maintenance it is necessary to analyze the factors of influence and criteria of success. Factors "requirements" and "criticality" of the medical device are elements on which the biomedical service has not little influence in terms of actions to be taken [19]. Managers are required to better use resources (Figure-2) to optimize the maintenance function:

![Figure-2. Maintenance in hospitals [Georgin et al 2005].](image)

**PREVIOUS RESEARCH: PERFORMANCE MEASUREMENT**

The performance evaluation in industry is currently a key element for the effective management of the company. The table below presents the main common methods found in the literature on performance measurement in the industrial sector:

<table>
<thead>
<tr>
<th>Methods</th>
<th>Objectives</th>
<th>Performance</th>
<th>Levels¹</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVA</td>
<td>Calculation of benefits</td>
<td>Gains</td>
<td>S</td>
<td>Albony, 1999 [22]</td>
</tr>
<tr>
<td>TQM</td>
<td>Quality Assurance</td>
<td>Quality</td>
<td>S / T / O</td>
<td>(Hill, 1977) [23]</td>
</tr>
<tr>
<td>Navigator Skandia</td>
<td>Determine the capital</td>
<td>Intellectual capital</td>
<td>S / T</td>
<td>Edvinsson et al 1997 [25]</td>
</tr>
<tr>
<td></td>
<td>human owned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSC</td>
<td>Evaluate global</td>
<td>4 axes BSC</td>
<td>S</td>
<td>Kaplan, 1992 [26]</td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIMSI</td>
<td>Conception dashboard</td>
<td>Defined indicators</td>
<td>T / O</td>
<td>Fernandez, 1998 [27]</td>
</tr>
<tr>
<td>ECOGRAI</td>
<td>Conception a system</td>
<td>Indicators of objectives</td>
<td>S / T / O</td>
<td>(Ducq et al, 2005) [28]</td>
</tr>
<tr>
<td></td>
<td>indicator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCOR</td>
<td>Evaluate global</td>
<td>Defined indicators</td>
<td>S / T / O</td>
<td>SCC¹ 1996</td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRISM</td>
<td>Performance measurement</td>
<td>parties taking</td>
<td>S</td>
<td>Neely et al 2001 [29]</td>
</tr>
<tr>
<td></td>
<td>processes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benchmarking</td>
<td>Performance compared to</td>
<td>Indicators of objectives</td>
<td>S / T / O</td>
<td>Anderson et al., 1999 [30]</td>
</tr>
<tr>
<td></td>
<td>reference organizations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COMMON PROBLEMS OF LOGISTICS AND MAINTENANCE IN HOSPITAL

Hospital logistics and hospital maintenance problems and common according to Figure below:

Figure-3. Common issues of logistics and maintenance in hospital.

In most hospitals, the logistics circuit contains medicines and medical devices. In this study, we focused on the common problems in the organizational aspect by performing a study on the impact of grouping pharmacies on the costs of maintenance of medical devices. In this context, the pharmacies grouping goal is to pool resources and master inventory, reduce waste and provide better centralized inventory management with visible traceability. In most cases, the grouping aims to reduce operations costs and increase system efficiency [31] [32].

PROPOSED METHODOLOGY

Integration costs in the concept of performance measurement plays a very important role in improving the performance of a health organization. For the drive, it is essential to develop a structured and flexible methodology that addresses the issues related to their requirements. In this perspective, we suggested a methodology that will allow us to calculate the financial cost and performance through indicators of the performance of the hospital maintenance, in order to determine the best organizational solution in terms of financial performance. The methodology involves two phases Figure-4. The first is to process analysis. The second is to evaluate the performance via costs as part of the actual situation of work:

Figure-4. Steps of the methodology.

First phase: Process Analysis

A.1 Choosing the process to be studied

Stock management is an aspect often neglected by hospital managers, which may yet bring a real benefit to the structure by improving the organization of the stock and allowing it to reduce costs. So this is a pilot process of hospitals performance in the Operational level, Tactics and Strategy, which is why we chose to work on the impact of grouping of maintenance pharmacies of medical devices.

A.2 Cartography of scenarios

In hospital logistics chain 'drugs and medical devices downstream and upstream are two types of structure that can be centralized and decentralized. Figure-5 shows logistics flows for both scenarios for medical devices:

Figure-5. Cartography of scenarios.

A.3 Analysis of logistics processes and maintenance of medical devices

In our prior work [33][34], we performed an analysis of the process of hospital supply chain for centralize and decentralized structures, but our current work is oriented towards the study of the impact of grouping pharmacies on the performance of the
Second phase: Performance evaluation

B.1 Modeling the costs of maintenance of medical devices

In order to model the costs of maintenance of medical devices, we need to introduce the following notations:

<table>
<thead>
<tr>
<th>Notations</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{puij}$</td>
<td>Tariff per hour preventive maintenance personal</td>
</tr>
<tr>
<td>$D_{puij}$</td>
<td>Duration conducted in time $j$ preventive intervention by maintenance personnel during the month $i$</td>
</tr>
<tr>
<td>$T_{cuij}$</td>
<td>Tariff per hour corrective maintenance personal</td>
</tr>
<tr>
<td>$D_{cij}$</td>
<td>Duration conducted in time $j$ corrective intervention by maintenance personnel during the month $i$</td>
</tr>
<tr>
<td>$N_{pimj}$</td>
<td>Number of spare parts $j$ consumed during the month $i$ for preventive interventions</td>
</tr>
<tr>
<td>$Cap_{ij}$</td>
<td>Unit purchase cost of spare parts consumed $j$ during the $i$ month for preventive interventions</td>
</tr>
<tr>
<td>$N_{cmij}$</td>
<td>Number of spare parts $j$ consumed during the $I$ month for corrective interventions</td>
</tr>
<tr>
<td>$Cap_{ij}$</td>
<td>Unit purchase cost of spare parts consumed $j$ during the $i$ month for corrective interventions</td>
</tr>
<tr>
<td>$Q_{ij}$</td>
<td>Quantity of stock of spare parts $j$ during the $I$ month</td>
</tr>
<tr>
<td>$Ca_{ij}$</td>
<td>Unit purchase cost of spare parts $j$ in stock during the month $i$</td>
</tr>
<tr>
<td>$Cu_{ij}$</td>
<td>Unit purchase cost of an urgent spare parts $j$ out during the $i$ month</td>
</tr>
<tr>
<td>$N_{rji}$</td>
<td>Number of products out to buy spare parts $j$ during the $i$ month</td>
</tr>
<tr>
<td>$C_{trpj}$</td>
<td>Transport cost emergency spare parts $j$ out during the $I$ month</td>
</tr>
<tr>
<td>$D_{ij}$</td>
<td>Waiting time by hour of day medical devices $j$ by the maintenance staff hospital during the month $i$</td>
</tr>
<tr>
<td>$L_{ij}$</td>
<td>Costs of losses caused by the unavailability of wait times $j$ medical devices during the month $i$</td>
</tr>
</tbody>
</table>

In our paper we modeled the costs that have a significant share in the maintenance budget of medical devices. The costs of subcontracting and training technicians are fixed monthly by contracts. They are not integrated into our mathematical model presented below:
B.2 Ratios maintenance of decision aid

In order to track and measure the effectiveness of maintenance, we use the following performance indicators:

Table-4. Ratios maintenance.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 = ( \frac{\text{Number of preventive intervention}}{\text{Number of preventive intervention + corrective}} )</td>
<td>Ratio gives the relative importance to preventive maintenance</td>
</tr>
<tr>
<td>R2 = ( \frac{\text{Number of corrective intervention}}{\text{Number of preventive intervention + corrective}} )</td>
<td>Ratio gives the relative importance to corrective maintenance</td>
</tr>
</tbody>
</table>

CASE STUDY

The case study focuses on the impact study of hospital logistics function in the case of stock grouping, on the performance of medical devices maintenance. In this context and in order to validate our work, we have applied our approach to a hospital in Morocco which is a made up of hospitals:

Table-5. DATA of 4 hospitals.

<table>
<thead>
<tr>
<th>Institutions</th>
<th>% of logistics in the budget</th>
<th>% Part of medical devices in the budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution H1</td>
<td>33%</td>
<td>12%</td>
</tr>
<tr>
<td>Institution H2</td>
<td>27%</td>
<td>10%</td>
</tr>
<tr>
<td>Institution H3</td>
<td>29%</td>
<td>14%</td>
</tr>
<tr>
<td>Institution H4</td>
<td>33%</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

In this context, we present the results of two parts:
- Evaluating the costs of maintenance of medical devices
- Evaluating the performance of the maintenance of medical devices.

We focused our study on a period of six months for the costs and maintenance of performance indicators. Our study will be based on a comparative approach of two scenarios (DS /CS):
- Evaluating the costs of maintenance of medical devices:

In this first study, we compare maintenance costs (Preventive, Corrective, storage, downtime) the hospital...
for both DS and CS scenarios. The results obtained are as follows:

From the results, we found that the total costs of maintenance are reduced in the case of the CS in relation to the DS during the six months. This improvement is due to:

- The grouping of interventions in terms of preventive maintenance minimizes the resources and material costs;

- An interchangeability of ideas gives a service with strong improvement and with the proper technique and quality of interventions among hospitals;

- Strategy centred maintenance will improve traceability and cost containment in the future;

- Reduction for placing orders at cost of spare parts;

- Interchangeability between hospitals in case of breakage or failure of medical devices;

- The stock centred minimizes costs of Biomedical Technicians (Moving, response time ...);

- Evaluating the performance of the maintenance of medical devices

In this section, we compare the performance indicators previously defined for both DS and CS scenarios. The results found are:

- Evolution of the indicator Preventive maintenance R1:
  - Preventive maintenance performed for the stock centred medical devices;
  - The grouping of interventions in terms of preventive maintenance minimizes the resources and material costs;
  - The stock centred facilitates the preparation and allocation of resources and implementation of interventions
  - The ease of scheduling and planning of preventive maintenance for the stock centred
  - The mastery and monitoring of traceability for maintenance managers in the hospital
  - The optimized because it is oriented pole and not distributed by hospital budget.

- Evolution of the indicator Corrective maintenance R2:
  - The case of scheduling and planning of preventive maintenance for the stock centred
  - The mastery and monitoring of traceability for maintenance managers in the hospital
  - The optimized because it is oriented pole and not distributed by hospital budget.
The results show that in the case of SC, the ratio of corrective maintenance decreases relative to the SD, this optimization is due to:

- Corrective maintenance performed for the stock centred medical devices;
- The grouping of interventions of preventive maintenance minimizes the resources and material costs;
- The stock centred facilitates, the preparation, allocation of resources and implementation of corrective actions;
- The ease of scheduling and planning of corrective maintenance for the stock centred;
- The mastery and monitoring of traceability for maintenance managers in the hospital and therefore the establishment of a reliable history in the future;
- The optimization because it is an oriented pole and not distributed by hospital budget;
- The stock increases the percentage centred preventive maintenance so that corrective maintenance minimizes stress.

CONCLUSIONS

The purpose of this paper is the demonstration of impact of the grouping of pharmacies on the performance of the maintenance of medical devices.

The logistics function in the hospital have a fundamental part of the health facility performance improvement, so we suggested a mathematical model for the maintenance of critical and indicators for monitoring the performance maintenance of the medical devices.

We have shown in the case study that a good stock and logistics management allows the hospital to reduce a lot of costs in favour of medical devices.

As a perspective of this work, we are currently working on another development that aims to introduce the dimensions and quality and safety costs in measuring the performance of the hospital supply chain.

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