



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.

CS: Centralized Structure

DS: Decentralized Structure

PM: Preventive Maintenance

CM: Corrective Maintenance

MAD: Moroccan Dirhams

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:

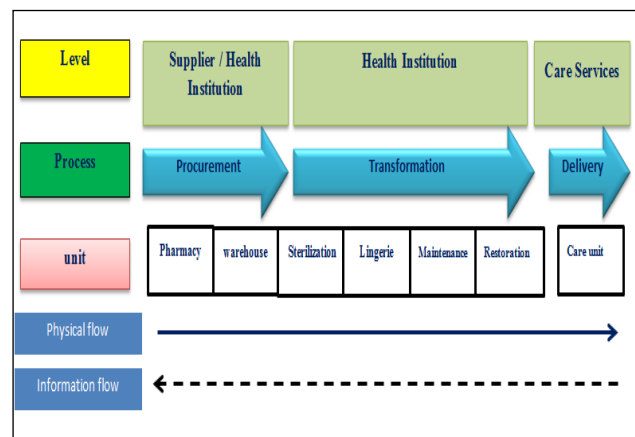


Figure-1. Supply chain in hospital.

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:

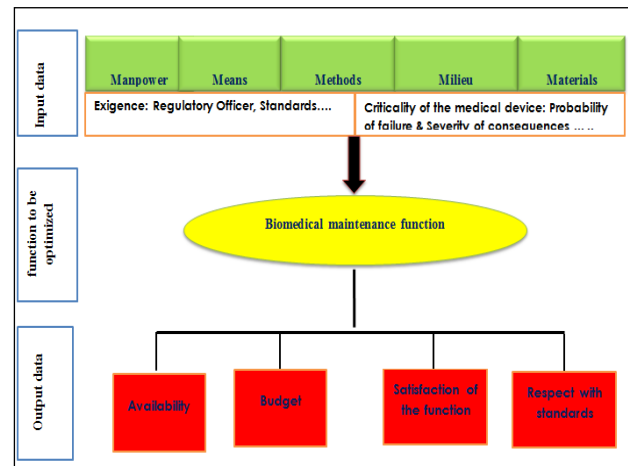


Figure-2. Maintenance in hospitals [Georgin *et al* 2005].

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-1. The performance measurement in industry.

Methods	Objectives	Performance	Levels ¹	References
Target Costing	Financial gain	Cost	S / T / O	Kato, 1993 [20]
ABC / ABM	Allocations of expenses	Cost	S / T	Kaplan et al, 1987 [21]
EVA	Calculation of benefits	Gains	S	Albony, 1999 [22]
TQM	Quality Assurance	Quality	S / T / O	(Hill, 1977) [23]
QFD	Quality Assurance	Quality	S / T / O	Akao, 2004 [24]
Navigator Skandia	Determine the capital human owned	Intellectual capital	S / T	Edvinsson et al 1997[25]
BSC	Evaluate global performance	4 axes BSC	S	Kaplan, 1992 [26]
GIMSI	Conception dashboard	Defined indicators	T / O	Fernandez, 1998 [27]
ECOGRAI	Conception a system indicator	Indicators of objectives	S / T / O	(Ducq et al, 2005) [28]
SCOR	Evaluate global performance	Defined indicators	S / T / O	SCC ¹ 1996
PRISM	Performance measurement processes	parties taking	S	Neely et al 2001 [29]
Benchmarking	Performance compared to reference organizations	Indicators of objectives	S / T / O	Anderson et al., 1999 [30]



COMMON PROBLEMS OF LOGISTICS AND MAINTENANCE IN HOSPITAL

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

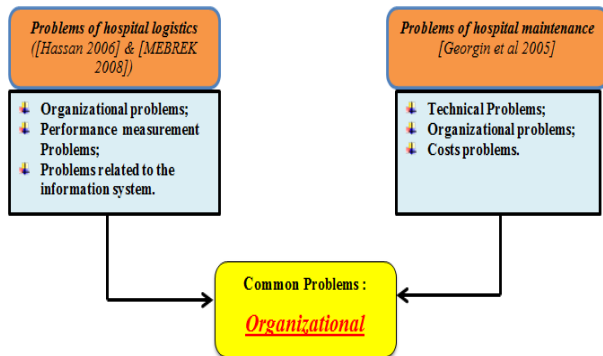


Figure-3. Common issues of logistics and maintenance in hospital.

In most hospitals, the logistics circuit contains medicines and medical devices [In this study, we worked on **medical devices**. 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:

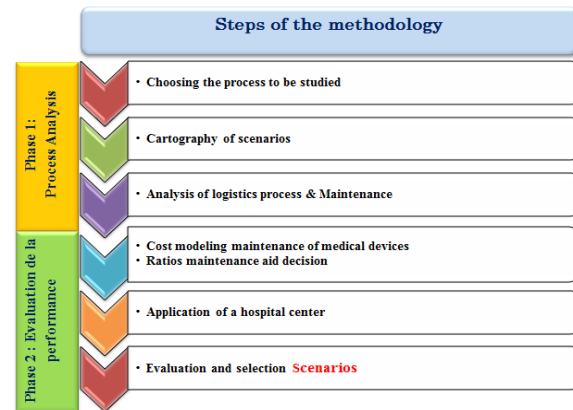


Figure-4. Steps of the methodology.

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 performance 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:

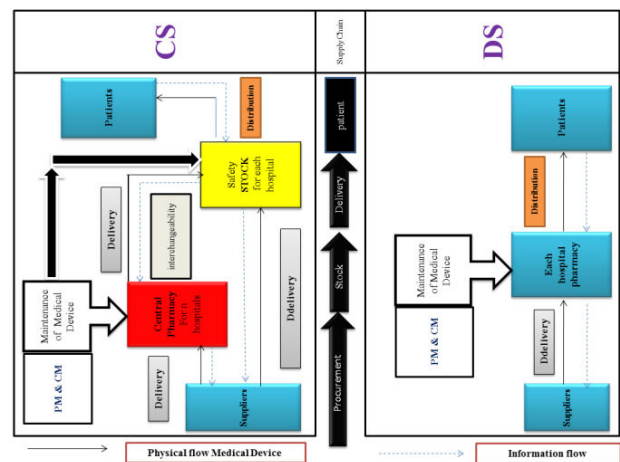


Figure-5. Cartography of scenarios.

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



maintenance function of *medical devices*. We summarized the difference between the two scenarios (CS and DS) on the performance of the maintenance function:

Table-2. Analysis of maintenance (DS and CS).

Maintenance performance	DS	CS
Corrective and Preventive Maintenance	-Preventive and corrective maintenance carried out for an independent hospital; -No grouping of interventions in terms of maintenance; -Traceability low; -Lack of interchangeability ideas for improving maintenance.	-Preventive and corrective maintenance performed to one centered stock; - grouping of spots in the maintenance plan; -A strong traceability gives a good history; -An interchangeable ideas for improving maintenance
Spare parts	-No exchange between hospitals in emergencies for Spare Parts; -Lack of interchangeability causes the rupture of spare parts; -Lack of traceability and the mastery of costs Parts.	-A stock of spare parts available centered; - Interchangeability between hospitals when necessary; -Order grouping spare parts minimizes the costs.
Human resources	-The geographic dispersion of impact hospital costs Biomedical Technicians (Moving, response time); -No interventions grouping increases the number of hospital service human resources.	-The stock centered minimize costs of Biomedical Technicians (Moving, response time); -The grouping of interventions stranglehold the number of human resources for the maintenance of hospital.
Budget Maintenance	-No grouping common controls of medical devices to minimize the budget; -No strategy centered (cluster) to optimize the budget; -Complexity monitoring performance indicators and lack of visibility caused by the geographical dispersion of medical devices.	-The grouping of the common controls of medical devices minimize budget -A strategy centered (cluster) optimizes the budget for maintenance. -Monitoring of highly visible and focused performance indicators.

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-3. The notations.

Notations	Descriptions
Tpu_{ij}	Tariff per hour preventive maintenance personal
Dp_{ij}	Duration conducted in time j preventive intervention by maintenance personnel during the month i
Tcu_{ij}	Tariff per hour corrective maintenance personal
Dc_{ij}	Duration conducted in time j corrective intervention by maintenance personnel during the month i
Npm_{ij}	Number of spare parts j consumed during the month i for preventive interventions
Cap_{ij}	Unit purchase cost of spare parts consumed j during the i month for preventive interventions
Ncm_{ij}	Number of spare parts j consumed during the I month for corrective interventions
Cac_{ij}	Unit purchase cost of spare parts consumed j during the i month for corrective interventions
Q_{ij}	Quantity of stock of spare parts j during the I month
Ca_{ij}	Unit purchase cost of spare parts j in stock during the month i
Cu_{ij}	Unit purchase cost of an urgent spare parts j out during the i month
Nr_{ij}	Number of products out to buy spare parts j during the i month
$Ctrp_{ij}$	Transport cost emergency spare parts j out during the I month
D_{ij}	Waiting time by hour of day medical devices j by the maintenance staff hospital during the month i
L_{ij}	Costs of losses caused by the unavailability of wait times j medical devices during the month i

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:

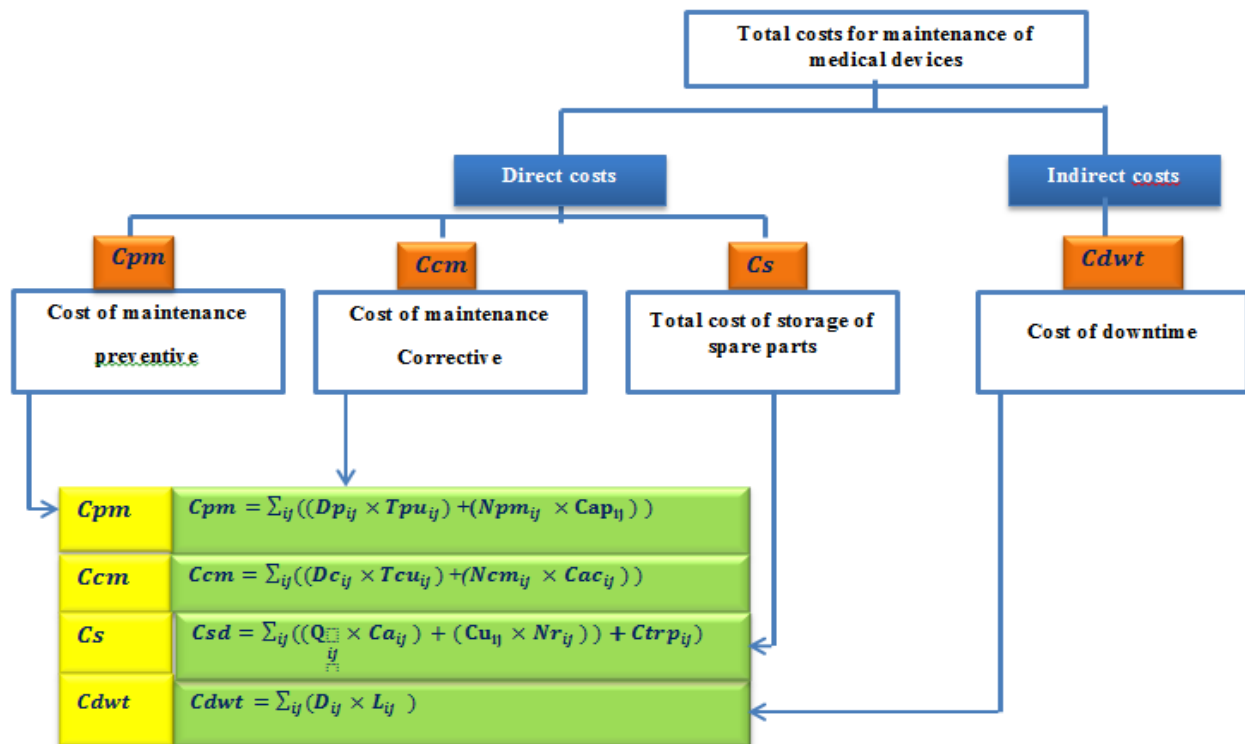


Figure-6. Model of maintenance of medical devices.

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.

Indicators	Descriptions
$R1 = \frac{\text{Number of preventive intervention}}{\text{Number of preventive intervention} + \text{corrective}}$	Ratio gives the relative importance to preventive maintenance
$R2 = \frac{\text{Number of corrective intervention}}{\text{Number of preventive intervention} + \text{corrective}}$	Ratio gives the relative importance to corrective maintenance

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.

Institutions	% of logistics in the budget	% Part of medical devices in the budget
Institution H1	33%	12%
Institution H2	27%	10%
Institution H3	29%	14%
Institution H4	33%	12,5 %

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:

Month		May	June	July	August	September	October
Costs of preventive maintenance (MAD)	DS	622 471,00	765 231,00	686 541,00	541 235,00	654 109,00	612 492,00
	CS	541 237,00	541 827,00	541 234,00	446 541,00	519 711,00	433 452,00
	DS/CS	1,15	1,41	1,27	1,21	1,26	1,41
Gain (CS-DS)/CS		-0,15	-0,41	-0,27	-0,21	-0,26	-0,41
Costs of corrective maintenance (MAD)	DS	428 760,00	522 123,00	512 342,00	487 152,00	491 562,00	499 982,00
	CS	332 876,00	406 541,00	401 762,00	387 761,00	343 562,00	381 761,00
	DS/CS	1,29	1,28	1,28	1,26	1,43	1,31
Gain (CS-DS)/CS		-0,29	-0,28	-0,28	-0,26	-0,43	-0,31
Total cost of spare parts (MAD)	DS	254 182,00	211 231,00	567 851,00	511 234,00	671 152,00	678 192,00
	CS	221 281,00	180 425,00	415 628,00	415 281,00	486 618,00	516 782,00
	DS/CS	1,15	1,17	1,37	1,23	1,38	1,31
Gain (CS-DS)/CS		-0,15	-0,17	-0,37	-0,23	-0,28	-0,31
Cost of downtime (MAD)	DS	521 987,00	399 829,00	391 872,00	213 489,00	267 876,00	298 176,00
	CS	293 987,00	284 987,00	299 896,00	198 982,00	214 561,00	247 987,00
	DS/CS	1,10	1,40	1,31	1,07	1,25	1,20
Gain (CS-DS)/CS		-0,10	-0,40	-0,31	-0,07	-0,25	-0,20
Total costs of maintenance (MAD)	DS	1 627 400,00	1 898 414,00	2 158 606,00	1 753 110,00	2 084 699,00	2 088 842,00
	CS	1 389 381,00	1 413 780,00	1 658 520,00	1 448 565,00	1 564 452,00	1 579 982,00
	DS/CS	1,17	1,34	1,30	1,21	1,33	1,32
Gain (CS-DS)/CS		-0,17	-0,34	-0,30	-0,21	-0,33	-0,32

Figure-7. Comparison between cost DS and CS of maintenance.

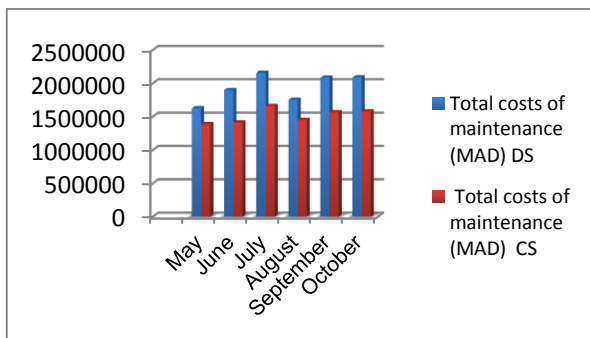


Figure-8. Evolution of maintenance costs between DS and CS.

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:

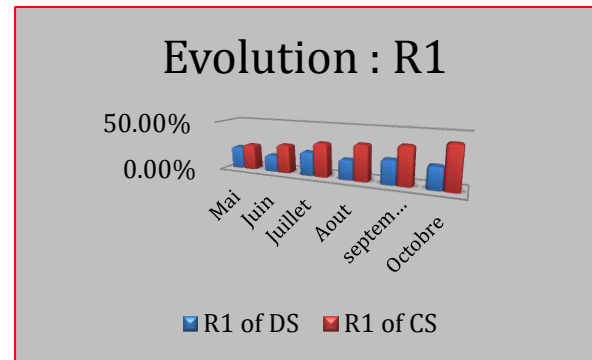


Figure-9. Evolution of the indicator R1.

The results show that in the case of CS, the ratio of preventive maintenance rise relative to the DS, this optimization is due to:

- -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:

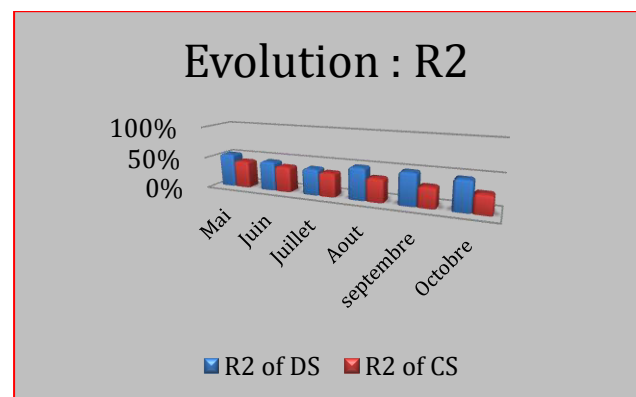


Figure-10. Evolution of the indicator R2.



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.

REFERENCES

- [1] Driss Serrou Abdellah Abouabdellah. 2015. Measuring the financial performance of the stock in the process of grouping pharmacies box. International Journal of Applied Engineering Research. ISSN 0973-4562, 10(13).
- [2] Driss Serrou Abdellah Abouabdellah. 2015. Study of Improved fiscal performance of hospital supply chain pharmacies by centralizing. The 45th International Conference on Computers and Industrial Engineering (CIE45) University of Lorraine, Metz, France, on October 28-30.
- [3] MarieAnne, Citton Giuliani, Grandhaye Jp, Abouabdellah A., A. Cherkaoui. The empowerment of patients factoring: Reporting to a holonic approach. Conference Service Systems and Service Management; ICSSSM'06. Volume: 1, pp. 398-403. ISBN: 1-4244-0450-9. INSPEC Accession Number: 9398031.DigitalObjectIdentifier:10.1109/ICSSSM.2006.320647. Troyes, France. Version Published: 2007-02-26
- [4] Abdellah Abouabdellah, Abdelghani Cherkaoui. 2014. Decision Support System for Predicting the degree of a cancer patient's empowerment. Journal of Theoretical and Applied Information Technology. ISSN: 1992-8645, E-ISSN: from 1817 to 3195. 60(3).
- [5] CSC. 1996. EHCR, Efficient Healthcare Consumer Response: Improving the Efficiency of Supply Chain the Healthcare. p. 118.
- [6] Sylvain LANDRY and Martin BEAULIEU in collaboration with Terry Friel and Claude R. Duguay Étude international best practices of hospital logistics, Montreal, CHAIN research group, specifications 00-05, p. 118.
- [7] Barney J. 1986. Organizational Culture: Can It Be a Source of Sustained Competitive Advantage? AcadManag Rev. 11: 656-665.
- [8] National Health Service. 2003. Clinical Outcomes Outcomes Indicators Group. Clinical.
- [9] Groene, O, N. Klazinga. 2008. The World Health Organization Performance Assessment Tool for Quality Improvement in Hospitals (PATH): an analysis of the pilot implementation in 37 Hospitals. Int. J Qual Health Care. 20 (3): 155-161.
- [10] DrissSerrou and Abdellahabouabdellah. 2015. Study grouping pharmacies impact on the performance of the hospital supply chain the 6th IESM Conference, Seville, Spain.
- [11] FREMONT Frédérique 2009. Hospital logistics. www.insset.upicardie.fr / file / rapport_sdl / The 20Logistique% CC% 80re.pdf 20Hospitale, 26/11/2010.
- [12] Hassan T. 2006. Hospital Logistics: organization of the pharmaceutical supply chain and consumables downstream flow optimization and single-use devices, sl: sn.



- [13] Housley CE. 1978. Hospital Materiel Management, Germantown, Aspen Systems Corporation. p. 353.
- [14] Henning, WK. 1980. The Financial Impact of Materials Management. Healthcare Financial Management. 34(2): 36-42.
- [15] Chow G., T. Heaver etHenriksson L. 1994. Logistics Performance: Definition and Measurement. International Journal of Physical Distribution and Logistics Management. 24(1).
- [16] A Rakotondranaivo and Augustin MD. Supplychain and innovation: what prospects for the organization of the flow of anticancer drugs from home hospital? GISEH'2012, Quebec, Canada.
- [17] DELOMENIE P. and M. YAHIEL. 1996. Drug Expenditure in the hospital, the French documentation. Paris.
- [18] Di Martinelly C., A. Guinet, Riane R. 2005. Hospital supply chain: modeling of pharmacy distribution process. In: proceedings of the International Industrial Engineering Conference (Besançon- France).
- [19] D. Georgin, j. Ntan, H .szymcrak, G. Farges. 2005. Management of extranalisation biomedical maintenance. ITBM-RBM News. 26(6). ELSEVIER.
- [20] Kato Y., costing 1993 Target support systems: lessons, Roma leading Japanese companies, Management Accounting Research. pp. 33-47.
- [21] Kaplan RS, Brown W. 1987. Accounting and Management: A field study perspective. Harvard Business School Press.
- [22] Albony M. 1999. The value is it something other than a fashionable discourse? File of the French Review of Management. p. 22.
- [23] Hill RT. 1977. Dynamic business strategy. Tat McGraw-Hill.
- [24] Akao Y. 2004. Quality function deployment Productivity Press.
- [25] Edvinsson L., Malone MS, 1997. Intellectual Capital: Realizing your company's true value by its Findings hidden brainpower. Irving Perkins Associates.
- [26] Kaplan RS, Norton DP. 1992. The Balanced Score Card: Measures That Drive Performance. Arvard Business Review. pp. 71-79.
- [27] -FatehMebrekThèse PhD. 2008: Tools for decision-based simulation for hospital logistics, application to a new hospital -University Blaise Pascal - Clermont-Ferrand II.
- [28] Fernandez A. 1998. The new dashboards for managers: decision entire project. Editions d'Organisation.
- [29] Ducq Y., Vallespir B. 2005. Definition and aggregation of a Performance Measurement System in three workshops using the Aeronautical ECOGRAI Method. International Journal of Production Planning and Control. 16(2): 163-177.
- [30] A. Neely, C. Adams, P. Crowe. 2001. The performance prism in practice, Measuring Business Excellence. 5(2): 6-12.
- [31] B. Andersen, T. Fagerhaug, Randmål S., J. Schulmaier, Prenninger J. 1999 Benchmarking supply chain management: finding best practices, Journal of Business & Industrial Marketing. 14: 378-389.
- [32] A. Guinet, E. Marcon. 2006. Project HRP2 (Hospitals: Combination, Sharing, Steering GISEH Conference 2006 Conference Proceedings GISEH 2006, Public Research Centre Henri Tudor. Vol. 1, Luxembourg, pp. 21-28 (2006/09).
- [33] Driss Serrou, Abdellah Abouabdellah. 2016. Logistics in the hospital: Methodology for measuring performance. ARPJ Journal of Engineering and Applied Sciences. ISSN 1819-6608. 11(5).
- [34] Driss SERROU, Abdellah ABOUABDELLAH An organizational strategy in order to optimize costs of medications return, The 3rd IEEE International Conference on Logistics Operations Management Gol 2016 –FEZ MOROCCO.