Redesigning the hospital supply chain for enhanced performance using a Lean methodology

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Abstract: The supply chain of medicines is a fundamental component of the health care system. It requires a good management in order to enhance hospital performance. This paper describes a model of designing the distribution network of health products within hospitals. Different scenarios are studied using multi-criteria analysis in order to identify the most appropriate design of the hospital supply chain in terms of costs reduction, accessibility and quality of care improvement.

Purpose: Define the most performing supply chain design based on three criteria: costs, accessibility and quality.

Design/methodology/approach: The *analytic hierarchy process* (*AHP*): a structured technique that assist decision makers to choose the best solution in complex situations taking in account multiple decision criteria.

Findings and Originality/value: This paper proposes to compare between six organizational scenarios of the hospital distribution network and in the end, to choose the most appropriate one based on three criteria: quality of services, accessibility and costs. Based on the AHP method, among the healthcare supply chain designs reviewed in the case study, the highest performance for pharmacies grouping is obtained by reducing costs and increasing the health products availability and quality. This grouping doesn't concern all the medicines and medical devices but only a part of them. The three organizational scenarios that represents the grouping of all health products (the second, the fourth and the fifth) occupy the last three ranks. The actual situation occupies the third rank. That is to say, that the reorganization of the hospital distribution network is required to improve the hospital performance.

Originality/value: The use of the AHP method to choose the most appropriate design of healthcare supply chain in a case study based on three decision criteria: costs, accessibility to health products and quality. The originality of the model is the assessment of performance in the light of the presumed perception of all actors of hospital (patients, medical staff and managers).

Keywords: Healthcare, Supply chain; Performance; multi-criteria analysis; quality, costs, accessibility, AHP.

1. Introduction

Improving the healthcare sector is one of the actual priorities of the Moroccan government and elsewhere. Under constraints of limited resources, a good governance of existing means is required. Hospitals must ensure high quality of care and patient satisfaction while minimizing costs and wastage. Pharmaceutical logistics represent a crucial part of hospitals budget. It requires a continuous improvement approach to optimize storage and distribution network.

The hospital supply chain is a complex process, it is characterized by the multiplicity of products, storage mode and distribution channels with different conflicting criteria. This paper proposes a multi-criteria method for choosing the most appropriate storage and distribution network in the hospital sector. Three principal criteria are taken into account: quality, accessibility and costs. Lean logistics is one of the essential methods used in the reorganization

of the hospital supply chain. Based on a global vision of the system, it allows identifying new ways of improvement having a global vision of the system, reducing wastage and ensuring a better management of resources. Several researches were conducted aiming for reducing all forms of costs related to the hospital supply chain starting from suppliers and ending with patients. An efficient supply chain must be waste-free to minimize costs and get health products to patients faster. In this context, our model compares designs on the baseline of their abilities to minimizing wastage costs as well. Patients assess quality of care provided by the hospital. Accessibility is limited in this work at the availability of healthcare products.

The first part presents the literature review of researches related to the use of multi-criteria methods for improving the hospital performance and criteria taken into account. The second part shows the interest of our study and proposes the multi-criteria model. The third part represents a case study using the AHP method and in the end, we finish by a results discussion and a conclusion. The purpose of our study is to develop a multi-criteria decision-making model aimed at redesigning the distribution network of the hospital sector to make flows more fluid, waste-free and faster.

2. Literature review

There is no universal model of the organizational performance. Approaches to improving performance differ depending on objectives and focuses (Quinn, R. E., Rohrbaugh, J., 1983). In the hospital sector, managers are searching for effectiveness (product with minimal costs); patients and doctors are looking for quality of care and satisfaction. Over the past few years, different researches were conducted to determine criteria for evaluating the hospital performance. Each one chooses criteria that it judged important for improvement. Naylor found that the hospital performance improvement is a result of the optimization of three criteria: quality, accessibility and costs (NAYLOR, C.D., 1999). Lemay (1999) identifies nine dimensions of the hospital performance [3]. Those dimensions are summarized in table1.

Performance dimension	Definition
Technical quality	The capacity to meet prescribed standards (human resources standards, technical, informational and financial standards).
Security	The capacity of the system to avoid errors and breakdowns that could impact the patient security.
Productivity	The ratio of produced services and used resources.
Patients, professionals and employees satisfaction	This dimension represents the ability of the system to meet the patient and health professional expectations.
Relevance	responding to the patient demand by a correct way
Return	The most global dimension of the performance, it represents the ratio of results and deployed resources.
Efficiency	It's the ratio of results on the health state of the patient and treatments procured. A good efficiency means the gain brought by treatments procured to the health state of the patient.
Technical efficiency	The ratio of treatment procured and resources used in it. A high technical efficiency means that the treatment harnesses the cheapest resources.
Accessibility	It measure the degree of constraints that are faced by the patient to receive medical care, it's about financial, organizational or temporal constraints

TABLE I. The nine dimensions of the hospital performance (LEMAY, 1999)

Those nine criteria could be assembled into the three criteria given by Naylor: quality, accessibility and costs (NAYLOR, C.D., 1999). In fact, the five first dimensions represent the

quality of service (technical quality, security, productivity, patient, professional and employees' satisfaction), the three following criteria: return, technical and global efficiency represent rather costs. The last criterion is accessibility.

In a survey conducted to illustrate dimensions of the hospital performance, authors identify 14 items, including quality of services and efficiency (Guisset, Sicotte, Leclercq, D'Hoore, 2002). The availability of health products in the opportune moment is also considered as an essential component of the hospital performance (Taher Hassan, 2006). It illustrates the temporal aspect of accessibility and so represents the most faced component of accessibility in the hospital sector, it's also the most important. In fact, the lack of pharmaceutical products in healthcare systems affects the proper functioning of care, if not it blocks the work within care services (BERETZ, PETIT, 2000), resulting in demotivated stuff and reduced quality of services provided [7].

In the literature, multiple criteria exist; some of them may be opposite or divergent. Consequently, improving the hospital performance requires the management of paradoxes (Quinn, R. E., Rohrbaugh, J., 1983). In that context, the multi-criteria analysis could help in the decision making when there is a need to choose the most appropriate solution taking on account several criteria. AHP is one of the most used multi-criteria decision making methods (Achillas, Moussiopoulos, Karagiannidis, Banias, Perkoulidis, 2013). Table2 presents some of research works in the hospital sector using the AHP method.

Topics of improvement	References
Hospital location selection	Vahidnia, Alesheikh, Alimohammadi, (2009). Sinuany-Stern, Mehrez, Tal, Shemuel, (1995).
Suppliers selection	Kahraman, Cebeci, Ulukan, (2003). Jenoui, Abouabdellah (2015).
Performance evaluation	Dey, Hariharan, Kumar, Moseley, (2004). Ahsan, Bartema (2004).
Healthcare waste management	Brent, Rogers, Ramabitsa-Siimane, et al. (2007) Karagiannidis, Papageorgiou, Perkoulidis, et al. (2010). Karamouz, Zahraie, Kerachian, et al. (2007)

TABLE II. contribution of the AHP method in the hospital sector

3. Proposed methodology

Lean thinking is more than a set of tools to eliminate waste. It's a new way of thinking about processes functioning aiming to make it more efficient and effective. For that, the methodology followed is composed of four steps:

- Analysis of current state processes.
- Identification of alternative ways to meet customer needs using different scenarios.
- Development of future state criteria.
- Analysis and comparison of alternatives based on future state criteria and choice of the most appropriate.

In a supply chain, distribution includes all steps taken to move and store a product from the supplier *to* the customer (Chopra, 2003). Distribution is an essential part of the hospital supply chain because it impacts directly the hospital performance and supply chain costs. There are different distribution models; each company chooses the most appropriate to its needs and specificities. In the hospital sector, we define six distribution designs based on the delivery and storage mode. Fig. 1 summarizes the six possible scenarios in the organization of a hospital supply chain.

Those designs are presented in the followed scenarios:

Scenario1: In this situation, different suppliers deliver to hospital pharmacies and then health products are delivered into services according to internal orders. All inventories are stored into

hospital pharmacies. In this situation, costs of transportation and storage are high (several orders to the same supplier, several locals…) with a high occurrence of stock shortage.

Scenario2: In this alternative, suppliers deliver to the central pharmacy that gathers all health products and distributes them to hospital pharmacies by orders. The benefits from centralization are highest for high value, low demand items with unpredictable demand (Chopra, 2003). The objective of this situation is to minimize stock shortage and transportation costs from suppliers to pharmacies.

Scenario3: This option is the mixture of the two previous scenarios; some products are delivered directly to hospital pharmacies and others to the central pharmacy. This situation aims to maximize the availability of health products that are vital and consumed frequently. It also helps avoiding stock shortage of common health products. Another advantage of this situation is the minimization of acquisition costs.

Scenario4: This situation assumes direct delivery from the central pharmacy to hospital services. This centralization gives the possibility to profit from the economy of scale by gathering several orders in a unique order. The biggest disadvantage of this situation is the frequency of transportation of health products to services. Products that are used frequently in a service are stored in it; this requires staff training on the storage norms and methods. The lack of training could result on defective products due to defective storage conditions.

Scenario5: In this scenario, the central pharmacy assembles all health products and deliver them to hospital pharmacies as the need arises with the possibility of direct delivery from the central pharmacy to care services.

Scenario6: in the last scenario, vital products are delivered directly to hospital pharmacies, and the other ones are stored at the central pharmacy. It provides also the possibility of direct delivery from the central pharmacy to care services.

To choose the most appropriate scenario that serves the best the hospital and its patients, it's necessary to take into account the economical function that is to optimize. Hospital logistics represents 30 to 40% of annual costs for which the pharmacy alone represents more than the half of expenditure (LANDRY, BEAULIEU, 2000), some researchers estimate costs of the hospital logistics at more than 45% (CHOW, HEAVER, HENRIKSSON, 1994).

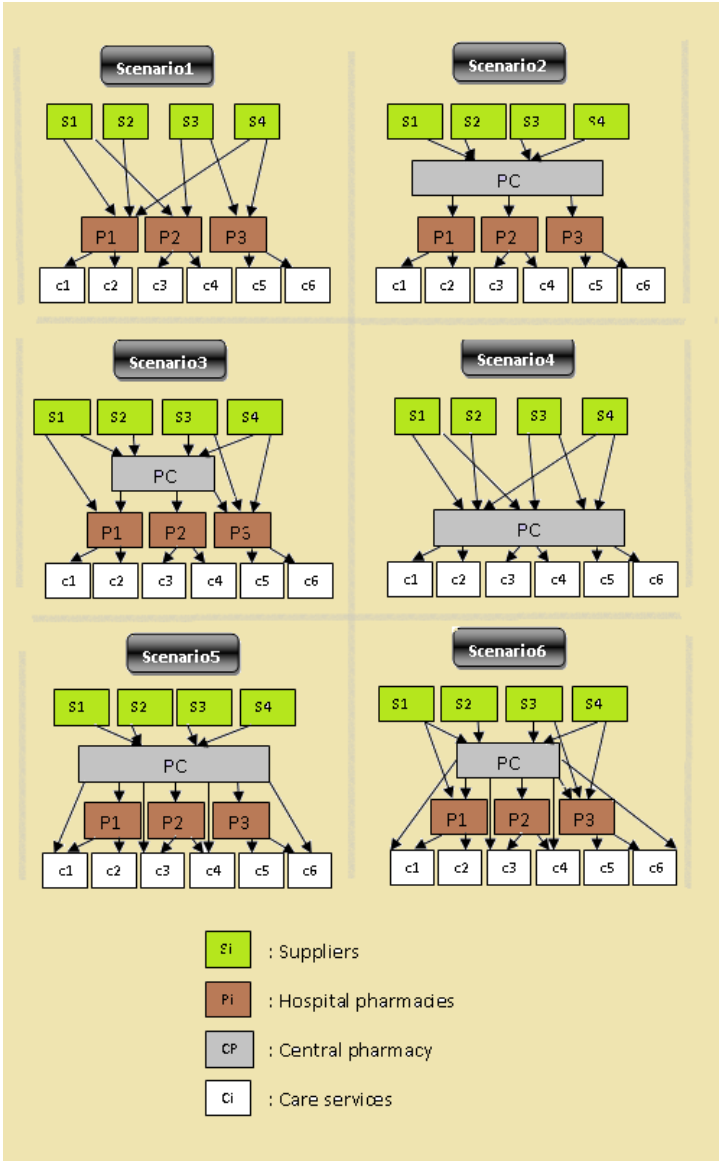

Figure 1: scenarios of medicines and medical devices distribution designs

According to Chopra (2003), changing the distribution network affects the following costs:

- Transportation costs (grouping of several orders or transporting each order alone…).
- Storage costs (depends on the number of places to be conditioned, stock shortage and expiration…)
- Acquisition costs (depends of the number of order placement, economies of scale, facilities…)
- Information costs (personal trainings, new materials...)

After data collection, our model allows comparing - on a scale of 1 to 9 - the four types of costs depending on frequencies and quantities of orders and changes made on the hospital information system in the case of a new design to meet its specifications.

But the comparison between several scenarios depending on their costs is not sufficient, especially in the healthcare sector where the quality of service and security of the patient is the nub of all its activities. Therefore, we propose to add two important criteria that are present in the majority of literature: the availability of products and the quality of services. This quality is measured by the response time which is the time between when the care service places an order and when it receives it.

Several multi-criteria decision making methods exist, the choice of the appropriate one is also considered as a multi-criteria problem (LAARIBI, 1995). No method is perfect (SCHÄRLIG, 1985), it depends on the problem to address. The AHP method is one of the multi-criteria methods that aim to prioritize alternatives. It allows the structuring of the problem into a hierarchical form that represents the goal, criteria to consider, sub-criteria and alternatives. Fig. 2 summarizes levels of the multi decision making problem to address.

The complexity of the healthcare supply chain makes it difficult to quantify the three dimensions of performance. Thereby, it's necessary to consider more levels in order to decompose it into a list of well specified sub-criteria and then ensure the appropriate weight to each one. AHP is an adequate method for healthcare system. Its hierarchy helps better understand the impact of different aspects on performance and their interactions and so results on reducing the complexity of evaluating the performance.

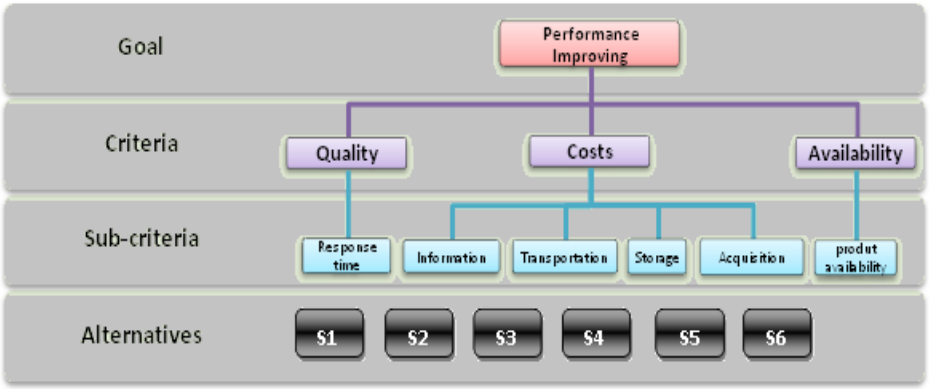

Figure 2: levels of the multi-criteria decision making problem

In cases where many alternatives need to be evaluated, the AHP ratings approach is often used. The biggest advantage of the AHP method is its use of pair wise comparisons to obtain a ratio scale of measurement (Liberatore, Nydick, 2008). That ratio scale allows the measurement and comparison between tangible and intangible criteria in terms of their ability to achieve the goal. For each criterion, a series of ratings or intensities is developed (for example, excellent, very good, good, fair, and poor). These intensities must be pair wise compared for each criterion, and then alternatives are evaluated by selecting the appropriate intensity for each criterion. Another advantage of the AHP method is that it allows inconsistency in judgment because human is not always consistent.

Our methodology consists on choosing the most performing scenario among the six scenarios presented previously. This choice is made using the AHP method as a multi-criteria decision making tool and based on three criteria: quality of services, accessibility and costs. To validate the proposed model, a case study was performed in a Public hospital in Morocco. Several interviews with medical staff, patients and healthcare managers were conducted.

4. Case study

To choose the most appropriate scenario, pair comparisons were made taking into accounts the three criteria and their sub criteria. The criteria weights are obtained from a questionnaire survey. This later was conducted with health care professionals: physicians and pharmacists. The survey consists on a pair comparison of the different sub-criteria using the decision matrix. Evaluation of the importance of each criterion is based on the scale proposed by Saaty, the developer of AHP method (Vargas, Saaty, 1991). This scale contains five levels as presented in table3.

Questionnaire survey was about to fill the decision matrix by comparing criteria based on measurement scale proposed by Saaty.

Description	Score
The two criteria have the same importance	1

The criterion on the line is a little more important than the one on the column	3
The criterion on the line is more important than the one on the column	5
The criterion on the line significantly more important than the one on the column	7
The criterion on the line is absolutely more important than the one on the column	9
The criterion on the line is a little less important than the one on the column	1/3
The criterion on the line is less important than the one on the column	1/5
The criterion on the line is significantly less important than the one on the column	1/7
The criterion on the line is absolutely less important than the one on the column	1/9

TABLE III. scale measurement for pair comparison of criteria (VARGAS, SAATY, 1991)

Results of pair comparisons are illustrated in table4. For each box in the table, final scores are the most frequent in the questionnaire replays.

Decision matrix	inventory	Transportation	Facilities	Information	Resoonse time	Product Availability	GeoMean
Inventory	1,000	1,000	3,000	3,000	0,200	0,143	0,797
Transportation	1,000	1,000	3,000	3,000	0,200	0,143	0,797
Facility & handling	0,333	0,333	1,000	1,000	0,143	0,111	0,348
Information	0,333	0,333	1,000	1,000	0,143	0,111	0,348
Response	5,000	5,000	7,000	7,000	1,000	0,333	2,724
Product Availability	7,000	7,000	9,000	9,000	3,000	1,000	4,779
Total	14,667	14,667	24,000	24,000	4,686	1,841	9,792

TABLE IV. Pair comparison of the criteria

Priority vectors or Eigen values represent weights that we are looking for. To compute the Eigen value, the geometrical average of each line is calculated and then divided by the sum of the geometrical averages that equals 9,792. Table5 represents results of weights of the criteria calculated in the decision making method.

criteria	Sub-criteria	Weights (Eigen Values)
Costs	Inventory	0,081
	Transportation	0,081
	Facility & handling	0,036
	Information	0,036
Quality	Response time	0,278
accessibility	Product Availability	0,488
	Total	1,0000

TABLE V. Criteria weights used in the AHP method

Pair comparisons are made between the six scenarios for each sub-criterion based on the measurement scale proposed by Saaty and using matrix as presented in the table 6 for the storage costs criterion. The diagonal elements of the matrix are always 1. The upper triangular matrix is filled up by actual judgment values. The lower triangular matrix is filled up by the reciprocal values of the upper triangular.

Storage	S1	S2	S3	S4	S5	S6	Geo mean	Priority Vector
S1	1,00	0,33	0,20	5,00	0,14	0,14	0,44	0,0508
S2	3,00	1,00	1,00	5,00	0,33	0,33	1,09	0,1271
S3	5,00	1,00	1,00	5,00	0,33	0,33	1,19	0,1383
S4	0,20	0,20	0,20	1,00	0,14	0,11	0,22	0,0262
S5	7,00	3,00	3,00	7,00	1,00	1,00	2,76	0,3219
S6	7,00	3,00	3,00	9,00	1,00	1,00	2,88	0,3357
Sum	23,20	8,53	8,40	32,00	2,95	2,92	8,57	1,00

TABLE VI. EXAMPLE OF A PAIR-WISE COMPARISON (STORAGE COSTS CRITERION)

To evaluate the consistence of the subjective judgment, a consistence ratio is calculated for every criterion. Table 7 summarizes the results of consistence ratios calculation. If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment. The consistence ratio is calculated using (1).

$c=(1/RI)*\sum V(i)*sum(i)$	(1)

With:

V(i): Priority vector of the scenario i. (from 1 to 6)

Sum(i): Sum of comparison score of the scenario i with all the six scenarios.

RI: Random consistency index (RI=1.24 for n=6).

Criteria	Sub-criteria	Consistence ratio (%)
Costs	Storage	3.11
	Transportation	8.97
	Facilities (acquisition)	5.03
	Information	2.21
Quality	Response time	3.43
Availability	Product Availability	4.00

TABLE VII. TABLE OF CONSISTENCY RATIO CALCULATIONS

According to table7, all consistence ratios are lower than 10%, which means that our judgments are acceptable. After filling the six pair comparison matrix, we calculate the score of each scenario based on criterion weights and results of priorities vectors calculated for each criterion using (2).

$S(i)=\sum w(j)*V(ij)$	(2)

With

W(j): Weight of the criterion j. (from 1 to 6)

V(ij): Priority vector of the criterion j relative to the scenario i.

Fig. 3 illustrates the ranking of the six scenarios based on the three criteria: quality, costs and availability.

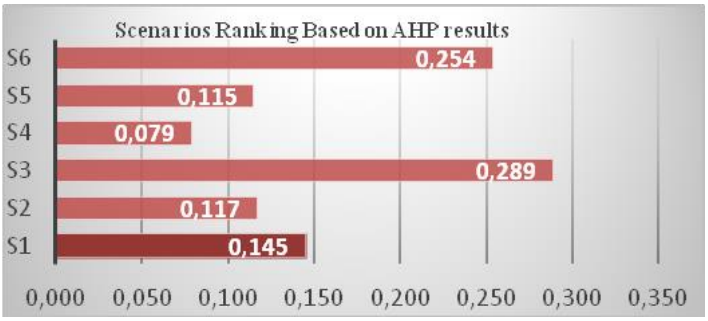

Figure 3: Scenarios ranking based on the AHP method

5. Discussion of results and conclusion

In the hospital sector where resources are limited, a good governance of existing means is required (Khlie, Abouabdellah, 2015a). Hospitals must ensure a good quality of service for patients while minimizing costs and maximizing health products availability. A continuous improvement approach must be implemented to always manage the hospital resources better (Khlie, Abouabdellah, 2015b). Lean is one of the most used approaches to tackle problems related to costs reduction and quality of services improvement. The key to maximizing quality and minimizing costs is to continuously look for new opportunities to boost efficiency. The organizational aspect is one of the most important aspects of the hospital supply chain. Changing *it* may have a noticeable impact on the hospital performance. This paper proposes to compare between six organizational scenarios of the hospital distribution network and to choose the most appropriate based on three criteria: quality of services, health products availability and costs. For that, a decision making method is used to facilitate the choice of the best scenario. As a result of the AHP method, the third scenario is the best. The grouping of pharmacies will allow a better hospital performance by reducing costs and increasing the health products availability and also quality. This grouping concerns just a part of medicines and medical devices. The second, fourth and fifth scenarios that represent the grouping of pharmacies including all health products occupy the three last ranks. The actual situation occupies the third rank after the third and sixth scenarios. That is to say, that the reorganization of the hospital distribution network is required to improve the hospital performance. This issue must be viewed in a wider perspective in the aim of improving the model and including more sub-criteria that reflect, as close as possible, the hospital sector and its specificities. A questionnaire will be conducted among patients to better understand their perception to performance and to identify their requirements and their main quality attributes. Another questionnaire will be intended for the medical staff to identify critical criteria that need to be improved to enhance the hospital performance, and the waste that impacts quality, costs and accessibility the most. The aim of those studies is to develop an integrated model for designing hospital supply chains.

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