Application to the Supply Chain of Drugs in a Public Hospital in Tunisia: Case Study in the Habib Bourguiba Hospital[1]

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ABSTRACT

For each of the steps, we present and justify the models we have chosen. Then, we apply these models in a public hospital "Habib Bourguiba" to manage the supply chain of drugs.

Background: In this paper, our objective is to build a performance evaluation system to drive the supply chain of drugs in a public hospital in Tunisia. For this, we consist in making a bibliographical synthesis on performance and the tools for evaluating it and offer an overview of all the methods and models proposed in the literature in order to adopt good practices. evaluation of the performance of supply chains.

Objective: From the perspective of developing performance appraisal system, it is imperative to have a robust methodology. In this article, we propose a methodology characterized by a nine-step approach that serves as a guide when designing a system of performance indicators to manage the drug supply chain within Habib Hospital. Bourguiba.

Methods: In this paper, we applied the ECOGRAI method. For this, we have identified for each decision center one or more objectives as well as the decision variables associated with them. Then, we determined the performance indicators for each decision center that are consistent with the objectives and the decision variables by referring to this method.

Keywords: *System Analysis and Technical Design; Just-In-Time; supply chain management; Graphes et Réseaux d'Activités Inter reliés; Supply Chain Operations Reference method; Technique for Order of Preference by Similarity to Ideal Solution and Analytic Hierarchy process.*

INTRODUCTION

The impact of hospital logistics on the performance of healthcare establishments is well known. Logistics activities hold great potential for optimizing hospital resources; the costs of these logistics activities can reach 30 to 50% of a hospital's total annual budget [Chow and Heaver 1994, Landry et al. (2010)], thus, the evaluation of the performance of hospital logistics is today considered a fundamental element for improving the quality of care service. Hospitals therefore now have an imperative need to manage the performance of logistics processes, mainly for pharmaceutical products, which represented 600 billion dollars worldwide in 2009 of global health expenditure

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[K. Xu et al 2018]. As a result, hospitals in Tunisia are increasingly resorting to management practices for their hospital pharmaceutical supply chain.

On the other hand, the need to develop an approach for the selection of performance indicators is a requirement confirmed by several authors.

- K.Moons et al. [2019], point out that there is a lack of methodological approaches to select relevant performance indicators to measure and evaluate the performance of the supply chain in the hospital setting.

- Bonvoisin [2011], affirms the difficulty of selecting the right performance management indicators via a hospital dashboard.

- Jawab et al [2016] affirm the need to develop a tool for selecting performance indicators in hospitals to ensure effective management of hospital logistics performance.

Therefore, the problem of our article is to build a performance evaluation system for the management of the supply chain of drugs within the public hospital "Habib Bourguiba" through a methodological approach declined in different stages of design and based on several tools.

The initial idea of this article concerns the definition of a multi-phase approach serving as a guide when designing a system of performance indicators for the management of the supply chain of drugs in the Habib Bourguiba hospital.

All the methods for defining and implementing performance indicators (ECOGRAI, ABC/ABM, BSC, SCOR), are based on essential elements which are modelling, understanding of the system concerned and the objectives to be achieved in order to determine the performance indicators [Bonvoisin, 2011; Benghalia 2015]. In addition, three notions are essential to performance evaluation: the objective, the measure and the action variable.

It is therefore essential to take these elements into account in the process of building a performance evaluation system. For this, the appropriate method is ECOGRAI because its “triple” principle makes it possible to link each performance indicator to at least one objective and to at least one decision variable.

Researchers claim that this method has a number of limitations (Benghalia 2015). For this, in order to respond to these limits and improve the ECOGRAI approach, this work consists in proposing an approach methodology declined in nine stages, in order to pilot the supply chain of drugs in the hospital ‘Habib Bourguiba’.

METHODOLOGY AND MATHEMATICAL MODEL

In this article, we present the application of the approach established previously in the hospital "Habib Bourguiba" in order to manage the supply chain of drugs.

The process was carried out at the Hospital and specifically in the pharmacy of the "HABIB Bourguiba" hospital, where the supply chain of drugs has experienced significant challenges.

We present in this paper the results obtained during the application of our approach.

Depending on the specificities of each step, these results are either presented in a comprehensive for the entire drug supply chain, either partially:

- Exhaustive results

  Step 1: Physical system modeling

  Step 2: Model the steering structure using the GRAI grid.

- Partial results

    - Step 1: Description of the decision-making centers according to the GRAI network
    - Step 2: Determination of objectives
    - Step 3: Identification of decision variables
    - Step 4: Analysis of local consistency
    - Step 5: Resolve conflicts: AHP/TOPSIS
    - Step 6: Determine the indicators and analysis of internal consistency
    - Step 7: Quantify the relationship between indicator/decision variable
    - Step 8: Design of the PI Information System (Performance Indicators).
    - Step 9: Design of the IP Performance Indicators Information System.

Application of the Methodology

The application of our approach took place in close collaboration with the technicians, nurses and pharmacists of the Habib Bourguiba hospital who also perform the function of pharmacy managers.

The exchanges took place repeatedly over several months and we made several on-site visits, in particular for the stage of the description of the physical and decision-making system and the various flows which flow there and also in the phase of application of multi-criteria decision aid methods and the mutual information method.

To create our case study, two sources of information are used: semi-structured interviews and observation. The interviews were collected through discussions with the actors who act on the management of the supply chain of drugs (pharmacists, technicians, nurses, managers), and the use of observation helps to enrich our understanding of the management of drug flows in the hospital, the exchanges developed repeatedly for several months.

Data collection method: Semi-structured interview

Semi-structured interviews with pharmacists, technicians, in-house pharmacists, etc. provided a large amount of information. The advantage of this type of interview is to guarantee the free expression of respondents within a framework set by the interview guide.

Data Collection Method: Observation

Direct observation is a powerful tool that allows the researcher to study phenomena in their natural environment, absorbing and noting the details and actions that take place.

The strength of the observations is that they provide data on the behaviors of the professionals involved in the management of medication Ford et al, (2008). The observations carried out in the Habib BOURGUIBA hospital have enabled us to enrich our understanding of the logistical processes, the flow of medications.

Step 1 : Determining the physical system

The performance evaluation process is always based on an interpretation model of the real system. Ducq [1999] asserts that "decision makers need to know the state of the controlled physical system at all times, in order to control the production system as precisely as possible to obtain optimal performance". Therefore, to optimize the supply chain, it is first necessary to understand its flows and the operating mechanisms of its actors. Understanding the current state of the system is a starting point for any optimization and analysis process.

The analysis of the existing or the modeling of physical system has been taken up by many authors. Lapiere [2003] identifies the management of pharmaceutical flows at the Croix-Rousse hospital using the SADT method (System Analysis and Design Technique), Ducq et al. [2004] model the physical system of an establishment using the actigram formalism derived from the IDEF0 method as part of the reorganization of a hospital system. Guinet et al. [2003] model hospital activity through the SADT method, they analyze the "What" (activities), the "Who" (actors), the "Where" (internalisation/externalisation), the "When" (modes of management) and the "How" (supports). A questionnaire was established for more than 600 health facilities to understand the current state of the pharmaceutical supply system. Baboli et al. [2003], study the flows of pharmaceutical products, from prescription to administration of these products to patients. Di Martinelly el al. (2005) adopt the process modeling approach to understand the operation of the real system of the pharmaceutical supply chain in a Belgian hospital.

Lean, definition and tools

Lean thinking appeared in the care sector in the early 2000s [Laursen et al. 2003] and represents the core of performance improvement approaches in the healthcare field [Manos et al. 2006]. But, compared to other areas (such as the automotive industry), health systems are lagging behind in the implementation of Lean concepts.

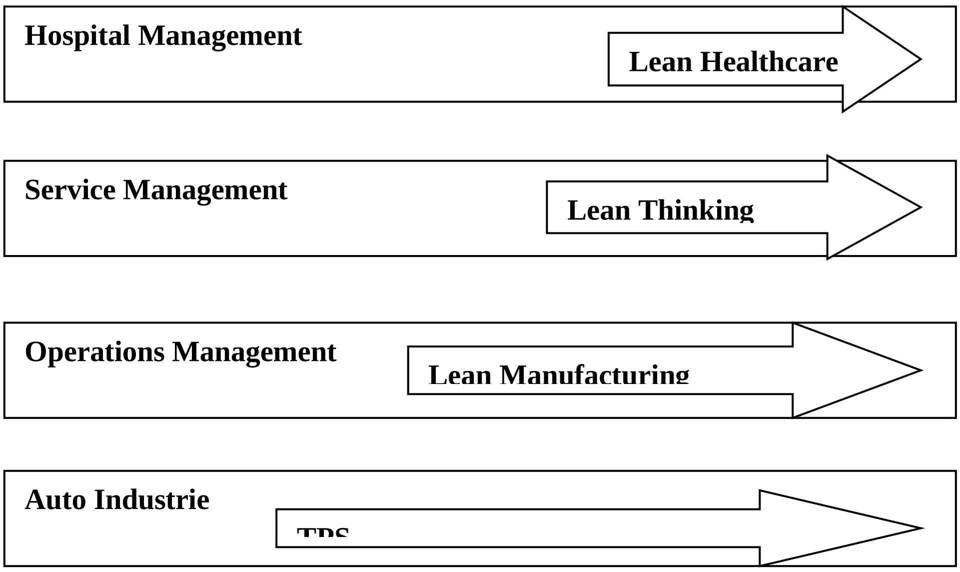


Figure 1: The Emergence of Lean Healthcare [Laursen et al. 2003]

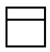
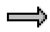
The Lean application to hospital logistics has been discussed by many researchers. Aptel et al. [2001], claim that the application of the notions of JIT (Just-In-Time) to supply chain management makes it possible to considerably minimize logistics costs. Similarly, Heinbuch [1995] analyzes the successful implementation of JIT in the secto hospital and proves that significant cost improvements are achieved. Landry and Beaulieu (2010) present a kanban (two-bin) system and discuss its implications for the inventory system. Venkateswaran et al. [2013] show that the application of the 5S methodology (Clear, Store, Clean, Maintain order and Be rigorous) in hospital warehouses can significantly increase inventory turnover.

Value Stream Mapping

Value Stream Mapping (VSM) is a Lean Manufacturing tool for visualizing and understanding the different flows of materials and information in the production process.

A VSM mapping is used to understand the current state of a logistics process, identify its dysfunctions and areas for improvement to improve the current state and make the necessary interventions for improvement. This representation uses standard graphic symbols (pictograms) (Table 1) to create a common language between users and facilitate understanding of the process.

Table 1: VSM pictograms

Pictograms	**Description**	pictograms	**Description**
	Customer and Vendor		Deposit of Storage
	Process or activities		Flows pushed
	Shipping by truck		Products sent to the customer
	Inventory (Item inventory)		Operator
	Information Electric		Safety stock

Step 2: Modeling of the decision-making system: choice of the GRAI method

Modeling makes it possible to better understand the functioning of the company either to help decision-making or to improve its functioning. Ducq and Vallespir [2004] assert that the interest of business modeling is to represent, then to understand and design decision-making mechanisms on the one hand, and on the other hand, the interest of business models is to show cooperative relationships and enable continuous progress in the operation of the supply chain. Thus, business modeling is used to improve the operating performance of the organization [Ducq Y, 2003].

Modeling in the hospital environment

In the field of Health, modeling in the hospital environment is practiced by several researchers because it makes it possible to understand complex organizations such as the hospital and makes it possible to verify the functioning and the robustness of a system [Bonvoisin 2011, Di Martinelly and al.2008]. Indeed, modeling methods take into account the structural and functional complexity of a logistics system [Zgaya and Hammadi 2016].

According to Nsamzinshuti et al. [2018], there is no specially designed method to model hospital processes. Therefore, the authors have used several methods to model the processes in the health environment as shown in the table 2.

Table 2: Modeling methods for the health system in the literature

Auteurs	**Méthode de Modélisation**	**Objectif de travail**
Jobin Marie-Hélène et al. (2003)	Areas of performance	Hospital logistics
Trilling (2006)	ARIS	Operation block
Chabane (2004)	SADT	Operation block
Ducq et al. (2004)	IDEF0 /GRAI	Modeling and design of a hospital system
Besombes et al. (2006)	GRAI	Consolidation of the Medical-Technical Platforms into a Hospital
Staccini et al. (2005)	IDEF0/SADT	Care processes
Hassan (2006)	SCOR, ARIS	Pharmaceutical circuit
Mebrek F. (2012)	Simulation	Hospital logistics

As part of our research, the method of analysis we choose is the GRAI method, for several reasons:

- The GRAI method is inspired by the ECOGRAI method which allows the definition and implementation of a system of performance indicators.

- GRAI is based on three decision-making levels (strategic, operational, tactical) which represent the three levels of management and also it represents a concrete approach to participatory implementation, which develops a dialogue between these different levels of the hierarchy.

- The applicability for issues affecting health activities has already been proven, in particular by Bonvoisin [2011] and Besombes [2006] who state that

"The adaptation of the method is interesting because it offers all actors and decision-makers a structuring tool to help formalize and objectivize the practices needed to define management and performance objectives".

- The GRAI method is an enterprise modeling method.

Step 3: Identify the objectives of the decision centers and coherence analysis

The purpose of this phase is to identify the objectives of the Decision Centers which are necessary for determining the appropriate performance indicators. After the construction of the GRAI grid, the next phase is the identification of the objectives of the decision-making centers and the analysis of coherence, this is step number two of the ECOGRAI method. A "top-down" approach is carried out by distinguishing between three sub-phases: the first consists in identifying the global objectives assigned to the system, the second consists in identifying the global objectives of each function of the production axis and the third the objectives at the level Decision Centers This approach is necessary to ensure proper coordination and synchronization of decision-making.

Therefore, the objectives of the production system are broken down into the decision centers of the GRAI grid, in which a decision center can have one or more objectives.

Step 4: Determine the decision variables

After defining the objectives of the four decision centers, the next step is to determine the decision variables on which we can act in order to achieve the objectives set. The determination of the decision variables represents step number three in the ECOGRAI method, but given the insufficiency of the method on the way of identifying the decision variables we were led to retain the Ishikawa diagram (or diagram of causes and effects), as a tool to identify decision variables. The Ishikawa diagram is applied by several researchers, Ibn el farouk et al. (2016) use the cause and effect diagram to identify the reasons for drug shortages in a Moroccan public hospital. According to this analysis, the shortage is due to the following reasons: lack of verification of orders, delivery incidents, late delivery of the annual order, unexpected increase in drug consumption and underestimation of the average consumption of drugs by care units. Benazzouz et al. (2018) identify the causes of drug supply chain dysfunction in public hospitals in Morocco using the Ishikawa diagram and claim that organizational and environmental factors can disrupt the proper functioning of the drug supply chain in hospitals.

Step 5: Analysis of objective consistency / decision variables

After defining the objectives and the means at their disposal to achieve them, it is important to ensure consistency in the system in order to guarantee effective management. To ensure this local consistency, we have also seen that it is necessary to establish the link between the objectives pursued and the decision variables, which is achieved by means of the Decision House.

Ducq (1999) creates the house of decision and applies this house in an industrial society of transformation and assembly. On the other hand, Bonvoisin (2011) establishes the link between the objectives pursued and the decision variables by means of the decision house in order to ensure the local coherence of the health production system (operating room). It builds four houses relating to the following four functions: F1 'Manage patient flows, F2 'Plan shifts and interventions', F3 'Manage human resources' and F4 'Manage equipment'.

The purpose of the decision house is therefore to ensure consistency between the objectives of the decision makers and their decision variables (DV), the first analysis amounts to verifying that each objective is at least linked to one decision variable, the the second amounts to verifying that each decision variable is at least linked to an objective and the third analysis concerns the study of the conflicts between the decision variables.

This step requires a significant investment and takes a large number of modifications before arriving at its final form. The absence of a relationship between the decision variables and the objectives could be observed at this stage. As a result, these decision variables were not retained.

With regard to the lines of decision potential, the levels mentioned have been determined according to the judgment of the decision-makers.

Step 6: Resolve conflicts between objectives and decision variables: AHP/TOPSIS

To improve the consistency of the decision-making structure and the overall performance of the hospital, it is necessary to determine the most important objectives. Thus, when there is a lack of means to achieve the objectives and certain objectives contribute more than others to improving the overall performance of the organization, in this case, the decision maker will have to choose between the objectives and the decision variables to improve the performance of the decision structure.

Indeed, improving the consistency of the decision-making structure requires the determination of the most important objectives on the one hand, and on the other hand the need to determine the optimal decision variable to achieve each objective.

To resolve the conflicts between the different objectives and the different decision variables that are assigned, we apply two multi-criteria decision support methods which are respectively 'Analytic Hierarchy process' Multi-criteria hierarchy method (AHP) and 'Technique for Order of Preference' method by 'Similarity to Ideal Solution' (TOPSIS).

The AHP method is based on pairwise comparisons and relies on expert judgment to establish priority scales.

This method is used to determine the weights of the objectives for each decision center in order to know the most important objectives. A comparison matrix between the objectives was made, the comparison coefficient aij varies from 1 to 9 according to the Saaty scale.

After determining the objective weights, we apply the TOPSIS method to determine the favorable ideal solution (favorable decision variable) for each objective.

The integration of the two tools in each decision house serves to improve the management system. Since we have developed a decision house for each decision center, then we apply the two methods (AHP, TOPSIS), for each decision center. The two multi-criteria analysis methods, AHP and TOPSIS are briefly presented in the following.

a) Determining objective weights using the AHP method

Definition of the AHP method

The Analytic Hierarchy Process (AHP), is a multi-criteria decision-making approach introduced by Saaty in the 1970s. AHP has attracted the interest of many researchers, mainly because of its mathematical properties interesting and the fact that the required input data are quite easy to obtain.

The AHP method consists of six steps, summarized as follows:

Step 1: Build a pairwise comparison matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix},$$

Where n denotes the number of items and a_{ij} denotes the comparison of item i to item j against each criterion.

Step 2: Divide each entry (a_{ij}) in each column of matrix A by its column total

$$A' = \begin{bmatrix} \frac{a_{11}}{\sum_{i\in R} a_{i1}} & \frac{a_{12}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{1n}}{\sum_{i\in R} a_{in}} \\ \frac{a_{21}}{\sum_{i\in R} a_{i1}} & \frac{a_{22}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{2n}}{\sum_{i\in R} a_{in}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{a_{n1}}{\sum_{i\in R} a_{i1}} & \frac{a_{n2}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{nn}}{\sum_{i\in R} a_{in}} \end{bmatrix},$$

Step 3: Calculate the average of the entries in each row of matrix A' to get the column vector.

$$C = \begin{bmatrix} c_{1k}^1 \\ \vdots \\ c_{nk}^1 \end{bmatrix} = \begin{bmatrix} \dfrac{\left(\dfrac{a_{11}}{\sum_{i \in R} a_{i1}} + \dfrac{a_{12}}{\sum_{i \in R} a_{i2}} + \cdots + \dfrac{a_{1n}}{\sum_{i \in R} a_{in}} \right)}{n} \\ \vdots \\ \dfrac{\left(\dfrac{a_{n1}}{\sum_{i \in R} a_{i1}} + \dfrac{a_{n2}}{\sum_{i \in R} a_{i2}} + \cdots + \dfrac{a_{nn}}{\sum_{i \in R} a_{in}} \right)}{n} \end{bmatrix},$$

Step 4: Consistency check

Multiply each entry in column i of matrix A. Then divide the sum of the values in row i to get another column vector.

$$\overline{C} = \begin{bmatrix} \overline{c}_{1k}^1 \\ \vdots \\ \overline{c}_{nk}^1 \end{bmatrix} = \begin{bmatrix} \dfrac{c_{1k}^1 a_{11} + c_{2k}^1 a_{12} + \cdots c_{nk}^1 a_{1n}}{c_{1k}^1} \\ \vdots \\ \dfrac{c_{1k}^1 a_{n1} + c_{2k}^1 a_{n2} + \cdots c_{nk}^1 a_{nn}}{c_{nk}^1} \end{bmatrix},$$

Where ***C*** refers to a weighted sum vector.

Step 5: Compute the means of the values in the vector C to obtain the maximum eigenvalue of the matrix A.

$$\lambda_{\max} = \frac{\sum_{i \in R} \overline{c}_{ik}^1}{n}.$$

$$A' = \begin{bmatrix} \frac{a_{11}}{\sum_{i\in R} a_{i1}} & \frac{a_{12}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{1n}}{\sum_{i\in R} a_{in}} \\ \frac{a_{21}}{\sum_{i\in R} a_{i1}} & \frac{a_{22}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{2n}}{\sum_{i\in R} a_{in}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{a_{n1}}{\sum_{i\in R} a_{i1}} & \frac{a_{n2}}{\sum_{i\in R} a_{i2}} & \cdots & \frac{a_{nn}}{\sum_{i\in R} a_{in}} \end{bmatrix},$$

Step 6: Calculate the consistency index

$$CI = \frac{\lambda_{\max} - n}{n-1}.$$

Step 7: Calculate the consistency rate

Where ***RI (n)*** is a random index whose value depends on the value of ***n***, given in the table.

$$CR = \frac{CI}{RI(n)},$$

Table 3: Average values of the random index

N	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Application of the AHP method using the Expert Choice software

After the determination of the pairwise comparison matrix of the different objectives of each decision center.

We use the "Expert Choice" software to determine the weights of the objectives as shown in the following figures. Expert Choice is a decision-making software based on multi-criteria decision-making.

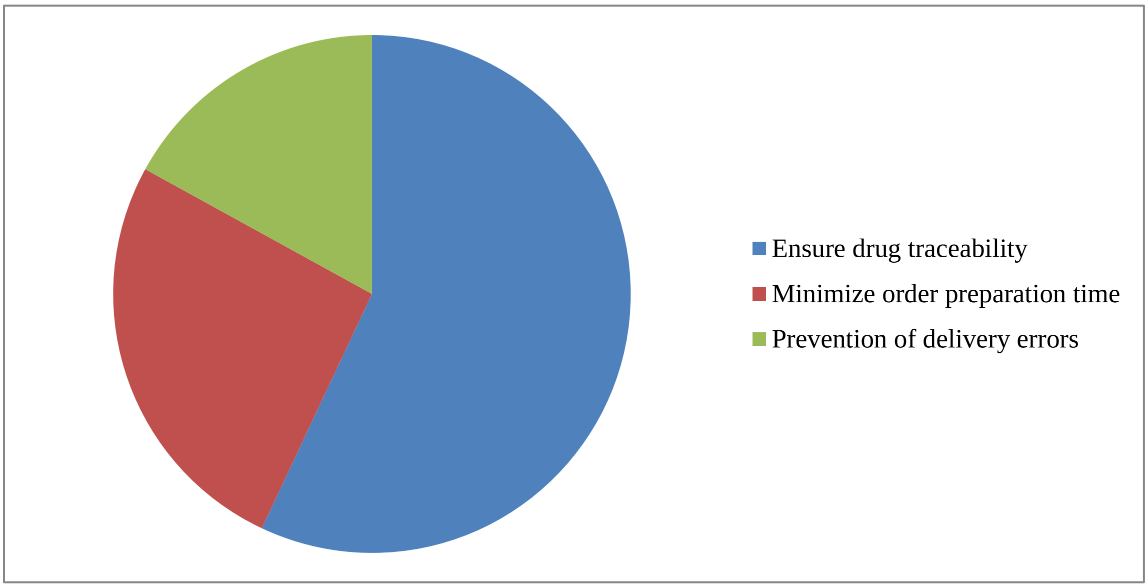


Figure 3: Diagrams in statistics of the objectives of the CD: GA30

b) Determining objective weights using the TOPSIS method

Definition of the TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a multi-criteria decision support method. It was developed in 1981 by Hwang and Yoon, the objective of which is to be able to classify in order of choice a certain number of alternatives on the basis of a set of favorable or unfavorable criteria. We will present in detail the steps to be followed step by step.

Step 1: Create a ranking decision matrix. The MCDM problem can be expressed as a matrix, as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

where A_1, A_2,..,Am are the viable alternatives from which the decision-makers must choose, C_1, C_2,., Cn are the criteria for measuring the alternative performance, x_{ij} is the qualification of the alternative A_i with respect to the criterion C_j, and w_j is the weight of the criterion C_j.

Step 2: Determine the normalized decision matrix and the normalized value n_{ij} is obtained using the formula:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i-1}^{m} x_{ij}^2}}$$

Where i= 1, 2, ., m, j= 1, 2, ., n.

Step 3: Determine the weighted normalized decision matrix, and the weighted normalized value vij is obtained using the formula:

$$v_{ij} = r_{ij} * w_j$$

Where w_j is the relative weight of the jth criterion or attribute and $\sum_{j=1}^{n} W_j = 1$

Step 4: Calculate the positive and negative ideal solutions, respectively:

$$A^{+} = \left\{ \left(\max_i v_{ij} \middle| j \in \Omega_b \right), \left(\min_i v_{ij} \middle| j \in \Omega_c \right) \right\} = \left\{ v_j^{+} \middle| j = 1, 2, \ldots, n \right\}$$

$$A^{-} = \left\{ \left(\min_i v_{ij} \middle| j \in \Omega_b \right), \left(\max_i v_{ij} \middle| j \in \Omega_c \right) \right\} = \left\{ v_j^{-} \middle| j = 1, 2, \ldots, n \right\}$$

Where Ω_b and Ω_C are the sets of criteria/attributes.

Step 5: Determine the value of the separation measurement. The separation of each alternative from the A+ solution is expressed by:

$$d_i^{+} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^{+} \right)^2}, \quad j = 1, 2, \ldots, n.$$

The separation of solution A- is expressed by:

$$d_i^{-} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^{-} \right)^2}, \quad j = 1, 2, \ldots, n$$

Step 6: Determine the proximity coefficient of the ideal solution and arrange in order of choice

$$cl_i^{+} = \frac{d_i^{-}}{d_i^{+} + d_i^{-}}.$$

The best alternative is the one that presents the closest relative proximity to the ideal solution.

Step 7: Identification of performance indicators and analysis of internal consistency

We have identified for each decision center one or more objectives as well as the decision variables associated with them. Now we will determine the performance indicators for each decision center that are consistent with the objectives and the decision variables by referring to the ECOGRAI method.

According to this method, an internal consistency analysis is carried out in each decision-making centre, at the level of the 'objective - decision variable - performance indicator' triplet. A triplet is considered coherent "if it is composed of an objective, one or more decision variables and one or more performance indicators and if the identified indicators make it possible to measure the achievement of the objectives [Ducq 1999, Bonvoisin 2011].

Two necessary conditions for the internal consistency of each decision-making center:

- Each objective of a decision-making center is linked to at least one indicator.
- Each indicator of this decision center is linked to at least one decision variable.

Step 8: Quantify the relationship between indicators and decision variables

Steering requires measuring the degree of dependence between indicators and decision variables [Addouche et al 2005]. To do this, the appropriate method is "mutual information" referring to information theory.

We quantify the relationship between each performance indicator and each decision variable to improve our management system.

The most effective decision variables are those that have maximum mutual information with the performance indicator.

We used MATLAB to calculate the mutual information between each indicator and each decision variable. By way of example, table 3 presents the calculation of the mutual information between the indicator (Order processing time) and the decision variables associated with this indicator.

Table 2: Mutual information between the performance indicator and each decision variable

	Variable de decision		
I_{ij}	**Id_1** Prescription computerized for all the services	**Id_2** Alert when from reception of a news prescription	**Id_3** Allow responsible for the pharmacy at access folder of patients

Indicator IP$_1^1$ Order processing time	1,2433	0,9896	0,9899

We find that all decision variables contribute to the achievement of objectives. Indeed, the most adequate decision variables are those that have mutual information. Maximum with the performance indicator. In other words, these are the variables that lead to the achievement of the objective set by the decision maker. Example, the decision variable that has maximum mutual information with the performance indicator "Order processing time" is the "computerized prescription", which contributes to the achievement of the objective “Minimize order preparation time”.

It is important to note that in total, the methodological approach allows the design of 26 performance indicators meeting the overall objective "optimize the supply chain of drugs in hospitals" and the resulting 12 objectives and 27 decision variables.

Step 9: Design of the IP Performance Indicators Information System

This step represents the identification of the basic information associated with the performance indicators. The specification sheet that we recommend containing several elements: the description of the indicator, the data profile, the graphic representation, the targets.

NUMERICAL RESULTS

Application of the TOPSIS method for the “Resupply of care services” CD :

Step 1: Matrix: Alternatives X Criteria (Analyze the choice of decision variables on the basis of the objectives) by assigning each decision variable the appropriate score based on the scale defined previously and with the help of experts (the pharmacists).

Table 4. Analyze the choice of decision variables based on the objectives of the CD GU20

	Ob1 Ensure drug traceability	**Ob 2 Minimize the time of preparation of the ordered**	**Ob3 Prevention of delivery errors**
VD1 Computerized prescription for all services	7	8	7
VD2 DJIN integration in All the services	7		8
VD3 Alert when receipt of a new prescription		5	
VD4 Distribution	6		7

Matrix: Alternatives X Criteria (Analyze the choice of decision variables based on the objectives).

Alternative	OB 1	0B 2	OB3
VD 1	7	8	7
VD 2	7		8
VD 3		5	
VD 4	6		7
VD 5		5	5
VD 6		6	3
VD 7	8	8	8

Step 2: Matrix normalized by criterion (attribute)

All the scores of the matrix of levels attributed to the criteria are normalized. To do this, we apply the formula shown opposite to obtain the new entries r_{ij} of the matrix.

Alternative	OB 1	0B 2	OB 3
VD 1	0,497	0,547	0,434
VD 2	0,497	0,000	0,496
		0,342	0,000
		0,000	0,434
		0,342	0,310
		0,410	0,186
		0,547	0,496

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

Step 3: Normalized and weighted matrix

In this step, we simply multiply all the entries (r_{ij}) of the normalized matrix by the weight associated with each criterion, so we proceed by column.

Weights (W): 0,5 0,3 0,2

Alternative	OB 1	0B 2	OB 3
VD 1	0,249	0,164	0,087
VD 2	0,249	0,000	0,099
VD 3	0,000	0,103	0,000
VD 4	0,213	0,000	0,087
VD 5	0,000	0,103	0,062
VD 6	0,000	0,123	0,037
VD 7	0,284	0,164	0,099

$$r_{ij} = w_j \times x_{ij}$$

Step 4 (a): Calculation of the ideal favorable solution A+

For each criterion (attribute), the most favorable associated value A+ is calculated according to the nature of the criterion (favorable or unfavourable).

Alternative	Ob1	Ob2	Ob3
VD 1	0,249	0,164	0,087
VD 2	0,249	0,000	0,099
VD 3	0,000	0,103	0,000
VD 4	0,213	0,000	0,087
VD 5	0,000	0,103	0,062
VD 6	0,000	0,123	0,037
VD 7	0,284	0,164	0,099

$$A^+ = \{max_i x_{ij} \ (i \in J^+) | min_i x_{ij} \ (i \in J^-)\}$$

$$A^+ = \{r_j^+ \ j = 1, \dots, m\}$$

For each objective, the most favorable associated decision variable is calculated. The decision variable most strongly associated with the objective (Ob1) “ensure drug traceability“ is the Decision Variable (VD7) “RFID / Code to bar“ with a score of 0.284.

Regarding the objective "minimize order preparation time" (Ob2), the most optimal decision variables are "Computerized prescription for all services" and "RFID / Barcode" with a score of 0.164 .

Regarding the objective “Prevention of dispensing errors” (Ob3), the most optimal decision variables are “DJIN integration in all services” and “RFID / Barcode” with a score of 0.099. These variables are easily leading to the achievement of objectives.

Step 4 (b): Calculation of the ideal unfavorable solution A-

For each criterion (attribute), the least favorable associated value A- is calculated according to the nature of the criterion (favorable or unfavorable).

Alternative	Ob1	Ob2	Ob3
VD 1	0,249	0,164	0,087
VD 2	0,249	0,000	0,099
VD 3	0,000	0,103	0,000
VD 4	0,213	0,000	0,087
VD 5	0,000	0,103	0,062
VD 6	0,000	0,123	0,037
VD 7	0,284	0,164	0,099

$$A^- = \{min_i x_{ij} \ (i \in J^+) | max_i x_{ij} \ (i \in J^-)\}$$

$$A^- = \{r_j^- \ j = 1, \dots, m\}$$

Regarding the objective “better use of storage capacity”, the least favorable decision variables are “sufficient capacity of storage areas” and “Apply the 5S method” with a score of 0.044.

The least favorable decision variable associated with the objective “Strengthen warehouse security” is the decision variable (DV7) “apply the 5S method” with a score of 0.147. With regard to the objective "avoid stock shortages and over-stocking" (Ob3), the least favorable decision variables are (VD1) "Storage the delivery by the FIFO method" and "Facilitate access to stored items” with a score of 0.213.

Application of the TOPSIS method for the “GA30 start ordering drugs” CD

Step1. Matrix: Alternatives X Criteria (Analyze the choice of decision variables based on the objectives).

Table 5. Analyze the choice of decision variables based on the objectives of the CD GA30

	Ob1 Ensure the availability of medicines at the right time and in the right place the hospital	**Ob2 Reduce the cost of supply**	**Ob3 Improving drug safety**
VD1 Computerize the flow of information between the hospital and the PCT	8	7	3
VD2 Use a dashboard to improve future predictions	7	4	
VD3 Alert for near expiry of a drug	5		
VD4 Extension of deposit		5	
VD5 : RFID IDs/ Barcode			8

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Alternative	OB 1	0B 2	OB3
VD 1	8	7	3
VD 2	7	4	
VD 3	5		
VD 4		5	
VD 5			8

Step 2: Normalized matrix by criterion (attribute)

Weights (W): 0,6 0,1 0,3

Alternative	OB 1	OB 2	OB 3
VD 1	0,681	0,738	0,351
VD 2	0,596	0,422	0,000
VD 3	0,426	0,000	0,000
VD 4	0,000	0,527	0,000
VD 5	0,000	0,000	0,936

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

Step 3: Normalized and weighted matrix

Weights (W): 0,6 0,1 0,3

Alternative	OB 1	0B 2	OB 3
VD 1	0,409	0,074	0,105
VD 2	0,358	0,042	0,000
VD 3	0,255	0,000	0,000
VD 4	0,000	0,053	0,000
VD 5	0,000	0,000	0,281

$$A^- = \{min_i x_{ij} \; (i \in J^+) | max_i x_{ij} \; (i \in J^-)\}$$

$$A^- = \{r_j^- \; j = 1, \ldots, m\}$$

Step 4 (a): Calculation of the ideal favorable solution A+

Alternative	Ob1	Ob2	Ob3
VD 1	0,409	0,074	0,105
VD 2	0,358	0,042	0,000
VD 3	0,255	0,000	0,000
VD 4	0,000	0,053	0,000
VD 5	0,000	0,000	0,281

$$A^+ = \{max_i x_{ij} \; (i \in J^+) | min_i x_{ij} \; (i \in J^-)\}$$

$$A^+ = \{r_j^+ \; j = 1, \ldots, m\}$$

To achieve the objective (Ob1) “ensure the availability of drugs at the right time and at the right place in the hospital“, the most favorable decision variable is (VD1) “Computerize the flow of information between the hospital and the PCT” with a score of 0.409.

With regard to the objective "reduce the cost of supply" (Ob2), the most optimal decision variable is (VD1) "Computerize the flow of information between the hospital and the PCT" with a score of 0,074.

With respect to the objective "improve drug safety" (Ob3), the most optimal decision variable is (VD 5) "RFID / Barcode identifications" with a score of 0.281. These variables are easily leading to the achievement of objectives.

Step 4 (b): Calculation of the ideal favorable solution A-

Alternative	Ob1	Ob2	Ob3
VD 1	0,409	0,074	0,105
VD 2	0,358	0,042	0,000
VD 3	0,255	0,000	0,000
VD 4	0,000	0,053	0,000
VD 5	0,000	0,000	0,281

The least favorable decision variable associated with the objective "to ensure the availability of drugs at the right time and at the right place in the hospital" is the decision variable (VD3)

"alert for the near expiration of a drug" with a score of 0.255. Regarding the objective "reduce the cost of supply" (Ob2), the least favorable decision variable is (VD2) "use a dashboard to improve future forecasts" with a score of 0.042. Regarding the objective "to improve the safety of medicines" (Ob3), the least favorable decision variable is (VD1) "to computerize the flow of information between the hospital and the PCT" with a score of 0.105.

CONCLUSION

In this article, we sought to build a performance evaluation system for the management of the supply chain of drugs within a public hospital "Habib Bourguiba" of Tunisia through a methodological approach which is declined in different stages and based on several tools.

The major challenge of our research work was to take up all the elements of the ECOGRAI method, and try to complete them by adding additional steps that sweep away all the essential elements for the establishment of a management system. effective performance evaluation and serving as a guide when defining a system of performance indicators for the management of the supply chain of drugs within the Habib Bourguiba hospital.

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