A Decision Support Platform based on Cross-Sorting Methods for the Selection of Modeling Methods

Case of the Hospital Supply Chain Performance Analysis

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***Abstract*—The hospital supply chain performance is a concept that qualifies the good governance, the continuous improvement and the optimization of human and material resources of the hospital system. Thus, several performance analysis methods have been proposed for qualifying organizational flows and resources management. The main goal of the present study is to expose a literature review of the main graphical modeling and performance analysis techniques used in different research projects in the hospital field. The literature review will be analyzed and complemented by a classification study of the previous techniques. It is about a review in which will be proposed a computer platform based on Multi-Criteria Decision Analysis. This platform uses fuzzy pairwise comparisons and cross-sorting methods. Finally, the classification study is chosen in order to highlight the most adapted techniques to the different characteristics and components of the hospital system as part of the overall support decision process.**

Keywords—Hospital supply chain; graphical modeling and performance analysis techniques; multi-criteria decision analysis; fuzzy pairwise comparisons; support decision process; computer platform; cross-sorting methods

I. Introduction

Currently, healthcare system challenges aren't limited to provide high-level service to patients at all costs, but it include optimization of hospitals expenses by decreasing costs and increasing productivity of resources.

In fact, for succeeding these challenges, the hospital decision makers must understand the complexity of the healthcare system at different levels. The authors of [1] have proposed: "*they need to recognize the types of sub-systems that constitute the whole healthcare system, the operations within each sub-system, the main bottlenecks and their causes, which actions are efficient and which are not, and the impact of changes and actions on the overall performance system*".

The major reflection of researchers in the healthcare field is the performance improvement of the hospital supply chain. Indeed, the authors of [2] explain that the improvement needs to be continuous by analyzing continually the performance in order to highlight aspects and action variables that influence directly the hospital system. For this purpose, several research works presented in the literature have treated the performance analysis concept in the hospital field and have used to this purpose different modeling methods. In fact, system performance analysis or improvement will be done by using modeling methods that allow describing the organization of the processes. The next step is about simulating it and comparing the different scenarios, or by analyzing and restructuring them.

In the hospital supply chain context, the development of modeling methods is done by considering the problems from which the system suffers and which hinder its development and performance.

Two types of performance analysis procedures exist [2]:

- **Priori approach:** To establish firstly a model, analyze and apply it to achieve its performance. The result will be compared with the predefined objectives and different changes of the model action variables will be proposed until stabilizing the model.
- **Posteriori approach:** To measure performances of an existing real system. Then, compare these measures with the predefined objectives and propose actions in order to improve the system.

In our present case, we will study the posteriori performance evaluation approach by considering the hospital system as an existing real system that the major studies focus on its identification and improvement.

However, the question is: Which of the several modeling methods to choose for describing effectively the hospital supply chain? Any system must to be modeled with respect to the strategy and the nature of the company's business. Therefore, our main work is based on the research in the literature of the several modeling methods, nature of stakeholders in their uses and recommendations of experts concerning their performances and limitations.

For this reason, we propose in this paper, the multi-Criteria decision analysis based on fuzzy pairwise comparisons to succeed the making decision process dedicated for choosing the best modeling methods.

The remainder of this paper is structured as follows: In section 2, we give an abstract about the different definitions given in the literature to hospital supply chain and its global structure. Then, we propose in section 3, a benchmark of the different modeling methods used in the hospital supply chain.

In section 4, we develop the classification study by identifying our methodology of research, determining criteria and applying the calculation algorithm.

II. Literature Review : Modeling Methods in Hospital Supply Chain

A. Hospital Supply Chain

The hospital system has been defined in the literature by all the flows (physical flow, informational flow and financial flow) which ensure the proper functioning of its institutions. The authors of [3] characterized the hospital system by an open system which is in interaction with external entities (logistic or medical service delivery entities). An analogy between hospital system and industrial system was mentioned in [4] and [5] by considering the process of production and in [3] by considering the orientation of flows and nature of stakeholders.

Thus, the performance in hospital supply chain has become instead of the qualification of the medical treatments a qualification of the sector organization and the quality of the care service [6]. Otherwise, the good management of material flow and patient flow are the keys for improving the hospital supply chain performance.

Several definitions of the hospital supply chain have been developed throughout the years. In fact, a set of dimensions have been developed to cover the integral definition of this supply chain (managerial and technical aspects [7]).

The notion of support logistics has been mentioned in [8]; it concerns supply, handling, maintenance and installation activities. The authors of [9] have based the hospital supply chain activities on three main activities: supply, production and distribution. Thus, according to [10] the hospital supply chain consists of the information, service, patients and physical flows management from the suppliers to the patients.

In [7], the author proposes the following definition: “Hospital supply chain is the set of design activities, planning, procurement management, manufacturing (goods and services), delivery and return management, from the provider to the beneficiary (patients), taking into account all the trajectories of the patients in the hospital without which there is no product flows (pharmaceutical). These activities are driven by the information flow between the various partners in the supply chain and lead to financial flows. The aim is to provide optimal service for the quality and safety of patient care”.

After scanning several definitions that were given by the literature, the next section will be dedicated to discover more deeply the structure and the different stakeholders of the hospital supply chain.

B. Structure of the Hospital Supply Chain

In this section, we will try to detail the global structure of the hospital supply chain, the different internal flows and those that are in interaction with external stakeholders.

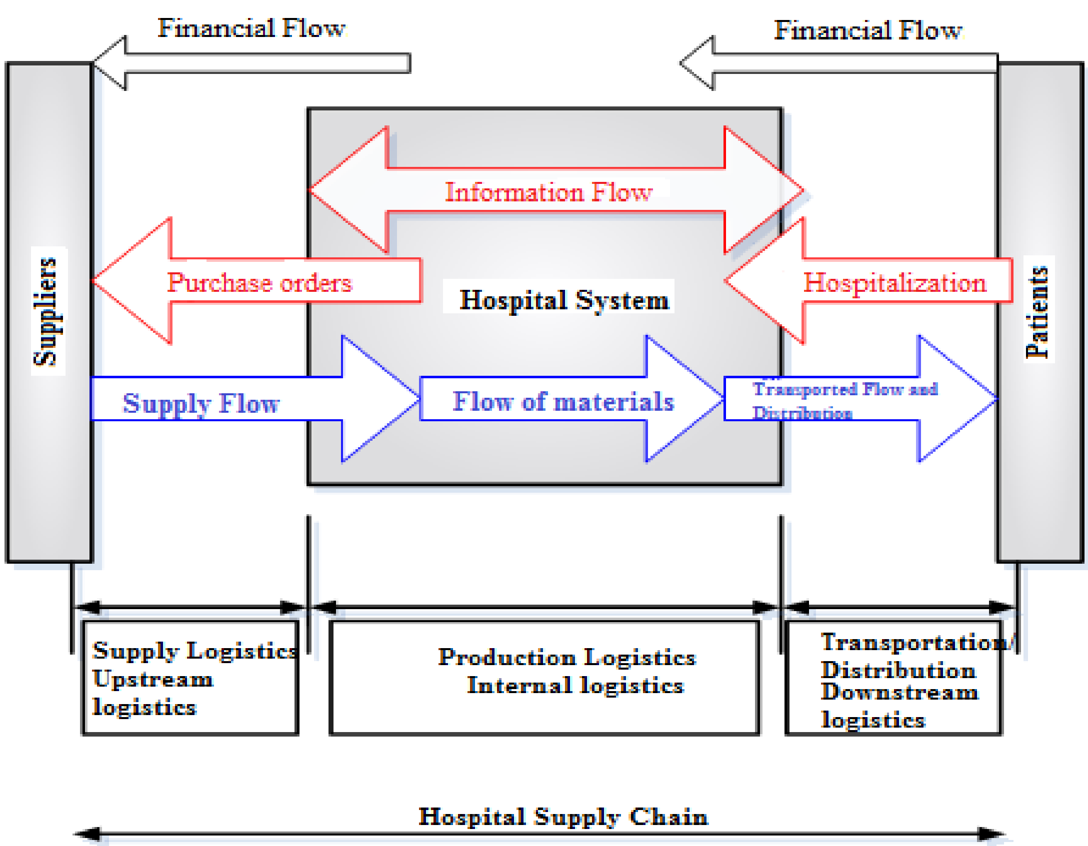


Fig. 1. The Structure of the Global Hospital Supply Chain According to [2].

According to [11], health institutions have five main activities and several types of inputs (patients and primary entrants) and outputs (intermediate and final outputs) are involved for the implementation of these activities. Otherwise, [12] was based to establish its proposal for the hospital supply chain structure on the following five factors which are related to the product life cycle: design, production, exploitation, distribution, destruction or recycling.

Moreover, [7] gives a proposal for the structure which focuses on the pharmaceutical component of the hospital system. Its proposal includes three levels. Firstly, an upstream level where the main actors are the suppliers or manufacturers of the pharmacy; The suppliers ensure the supply of pharmaceutical products to the pharmacy. Secondly, a first downstream level which characterizes the relationship between the pharmacy and the other services. The main activity of the pharmacy is to provide the pharmaceutical products received from the suppliers after or without transformation to the different hospital services. Finally, a second downstream level that concludes stocks management, returns management and the supply of pharmaceutical products to patients.

From the previous definitions, it is proposed a structure that implements the different levels and components of the hospital supply [2] (see Figure1):

C. Graphical Modeling Methods

The literature has been enriched in recent years by several researches dealing with the problems of hospital system. In this section, we analyze the different cases treated in the literature that concern the hospital supply chain and in which researchers have proposed performance analysis methods especially the graphical modeling methods.

The modeling studies that are present in the literature concern the main production flow within the hospital, patient flows, administrative flows and resources which are related to primary services as well as operating theaters, emergency units, consultation centers, etc. According to [7], the difficulties of optimizing flows and stocks pushed the managers to find balances and to discover new ways in order to rationalize expenditures and seek refined solutions to these new problems.

The remainder of this work focuses on methods that are used in the modeling and simulation approach. It is about modeling and simulating the action data by evaluating the performance of the system in order to reach the objectives represented by an interesting number of performance indicators [13].

In fact, it can be referred to two different types of studies [14]: studies that concern the planning and optimization of care production units ([15]; [16]) and that of operations management which propose models and the theories dealing with the current problems that the patient circuit knows in the hospital ([17];[18]; [7]; [6]).

For example, the author of [19] have linked in his work the following objectives to the modeling approach:

- Improvement of the decision-making organization and reduction of the hospitalization duration [20]
- Reduction of the waiting time in emergency unit [21]
- Reduction of the time spent by the patient in the emergency units and improvement of its performances [22]
- Restructuration of medical personnel assignment problem [23]
- Minimization of the pharmaceutical supply chain expenditures.

In each case study, the literature includes a framework rich in modeling methods and their attributions.

The modeling and simulation approach has used by the authors [6] to minimize the cycle time of the patient journey in emergency department, to improve the medicine drugs circuit in Moroccan hospital system [1] and to optimize the blood transfusion process in Blood Transfusion Regional Center of Casablanca-Morocco [23].

The authors of [6] used for the modeling part the IDEF3x method and for the simulation part the queue networks. The queuing theory was used by [22] in order to insure the optimal service rate by determining the adequate combinations of human and materiel resources to be attributed to each inpatient unit room. Researchers are also developed and adapted industrial platforms in order to exploit their strengths in producing outstanding results. For example, the industrial planning software (PREACTOR) was used by the author [18] for managing in real time the patient's trajectory in the hydrotherapy and the radiotherapy centers.

In the table below (table I), we indicate works applying modeling methods in the hospital supply chain.

TABLE I. GRAPHICAL MODELING METHODS APPLYED IN HOSPITAL SUPPLY CHAIN

Authors	**Modeling Method**	**Hospital Field**	**Flow Type**
[24]	SADT	Blood transfusion	Informational flow
[25]	UML, SADT Petri Networks	Hospital Processes	Patient flow, informational flow
[26]	SADT	Emergency department	Patient flow
[6]	SADT	Emergency department	Patient flow
[27]	UML	Hospital processes	Patient flow
[28]	UML, SADT Petri Networks	Production and Distribution supply chain	Materials flow
[29]	UML, Petri Net	Hospital supply chain	Drugs flow
[30]	ARIS	Hospital Supply Chain	Supply chain flows
[31]	BPMN	Hospital Materials	Patient and materials flows
[32]	BPMN, SCOR	Drugs supply chain	Drugs flow
[33]	BPM	Hospital Supply Chain	Pharmaceutical Products flow

In a similar study, [34] has attempted to analyze a set of modeling methods using the criteria proposed by CEN [35] to develop a system of performance indicators. In this context, a classification platform that will allow choosing the appropriate modeling method is proposed in the next section.

III. The Decision Support Platform for the Selection of Modeling Methods in the Hospital Supply Chain

A. *Research Methodology*

The global methodology adopted in this work for analyzing the literature review and developing the decision support platform is summarized on the following steps:

Step 1: To look for the modeling methods used in the hospital system literature. It is about the web-based search in electronic databases. The electronic databases chosen are as follows:

- Thomason Reuters;
- ScienceDirect;
- DPLB;
- Springer;
- IEEE;
- IJACSA,
- Google scholar,

In this step, the following key words were adopted: hospital supply chain; performance analysis techniques; modeling; simulation.

Step 2: To sort the works obtained in the previous step by remaining in the study framework; refine the obtained database and eliminate any work that does not align with the main objective.

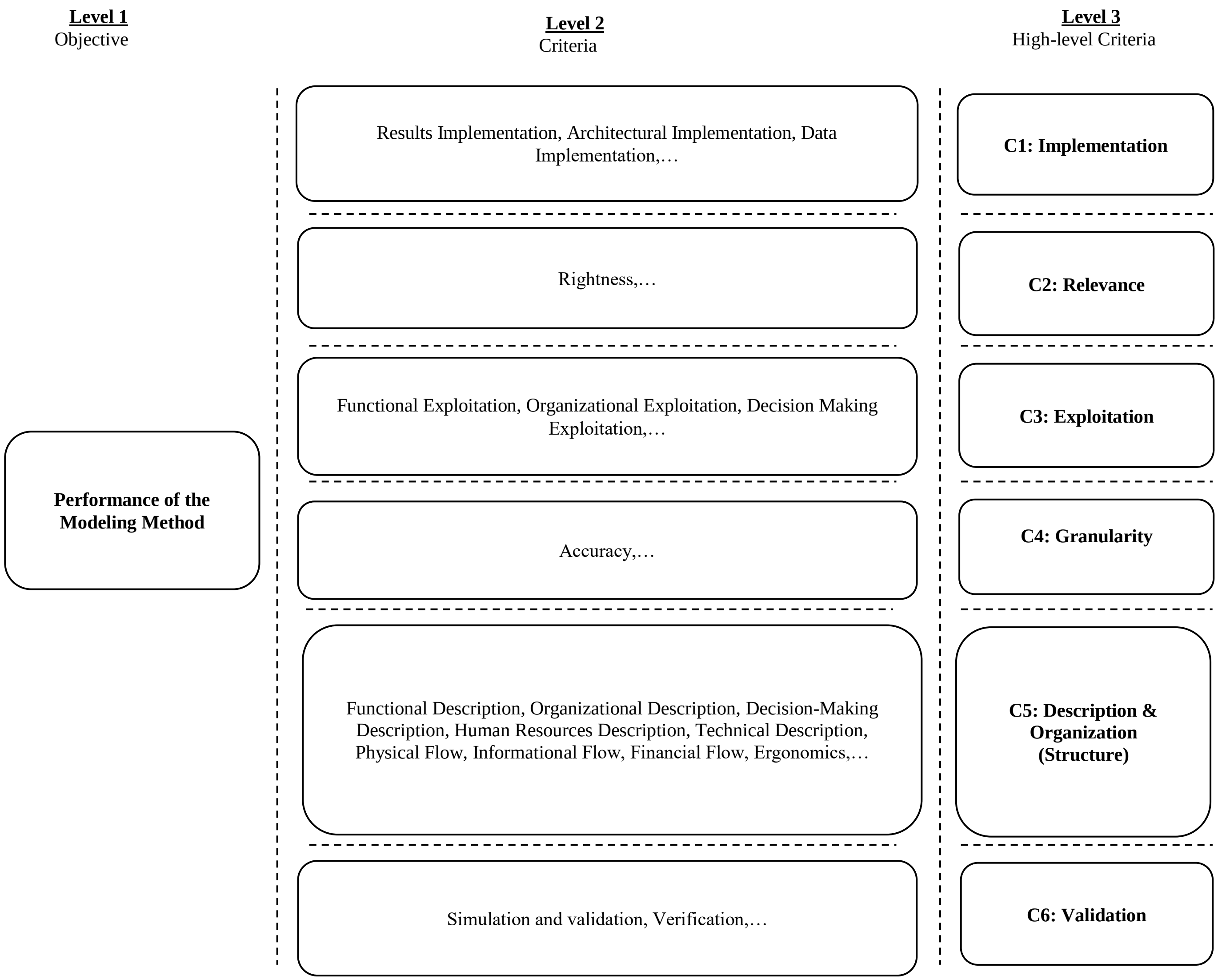


Fig. 2. Criteria of the Modeling Methods Performance.

Step 3: To develop a platform based on the cross sorting methods and fuzzy pairwise comparisons for classifying modeling methods that are used in the literature; this classification framework uses the following criteria: Functional Description, Organizational Description, Decision-Making Description, Human Resources Description, Technical Description, Physical Flow, Information Flow, Financial Flow, Ergonomics, Rightness, Functional Exploitation, Organizational Exploitation, Decision Making Exploitation, Accuracy, Results Implementation, Architectural Implementation, Data Implementation, Simulation and validation, verification.

Step 4: To choose experts and request from them to fill the comparison matrices (comparison matrices of criteria and comparison matrix of methods).

Step 5: To classify methods of the literature according to the platform based on the cross sorting methods.

B. The Modeling Methods: Application of the Classification Study

Our classification study aims to analyze the adaptability of the modeling methods, used in the process of performance analysis, to the various components of the hospital supply chain. To do this, we tried at first to gather the most used techniques in the literature concerning the hospital sector and to classify them according to six criteria as developed on the next section (see Figure 2) by using multi-criterion decision analysis based on fuzzy pairwise comparisons.

1) Criteria of Modeling Methods Performance: In this section, we present criteria that are adopted for the comparison between different modeling methods. At first, the principal criteria of the modeling methods performance will be detailed. Secondly, the criteria will be grouped on six principal axes: Implementation, Relevance, Exploitation, Granularity, Description & Organization (Structure) and Validation (see Figure 2).

2) Calculation of Final Scores (Scores of Criteria and Scores of Modeling Methods)

a) Fuzzy Logic: Definition

The fuzzy logic is based on the use of fuzzy numbers which are defined by distribution of possibility. The membership function μ identify this distribution by associating digital elements with different degrees of the possibility that vary between 0 and 1 [36]. In fact, the membership functions exist in different forms: Triangular, trapezoidal or Gaussian form [37].

The use of the fuzzy logic is large in the literature. In the rest of this work, it is opted for the triangular function adopted by [38] in their extension of the principle of least-squares logarithmic regression for taking into account the inaccuracy. The triangular function is defined by the lower value (c_l), the modal value (c_m) and the upper value (c_u) as shown in the figure below (Figure 3).

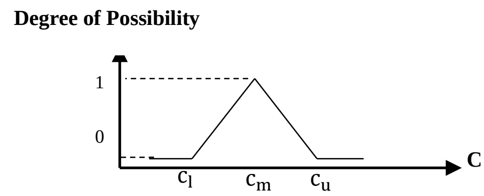


Fig. 3. Triangular Fuzzy Number.

b) Description of the Calculation Algorithm

To determinate the final scores of the studied modeling methods considering the six performance criteria of decision which are cited above, it is opted for the fuzzy multi criteria method proposed by [38] and modified by [39]. The choice of this method was not made arbitrarily but was based on the originality of his theory in terms of taking into account the inaccuracy in spite of the extensions which have been proposed later and which merely adopt other logics which also have their limitations or sometimes violate the assumptions of validity of the initial approach (for example the adoption of FWA algorithm in deterministic methods [36]).

In order to attack the allocation of triangular fuzzy pairwise comparisons, a decision committee of 3 members is defined A1, A2, A3.

The method will be applied in three main phases: Firstly, fuzzy weights $\tilde{\alpha}_i = (\alpha_{il}, \alpha_{im}, \alpha_{iu})$ i=1,…,m will be assigned to the performance criteria of decision based on fuzzy pairwise comparisons $\widetilde{r_{ijk}} = (r_{ijkl}, r_{ijkm}, r_{ijku})$ (i, j=1,…,m) given by committee members k=1,2,3. Secondly, fuzzy weights $\widetilde{\beta_{ij}} = (\beta_{ijl}, \beta_{ijm}, \beta_{iju})$ ($i, j = 1, \dots, n$) will be estimated for methods under each of the criteria separately. Lastly, the final scores of methods ω_j j=1, …, n are calculated by the aggregation of the calculated weights according to the formula below:

$$\omega_j = \sum_{i=1}^{m} \alpha_i \beta_{ij} \quad j = 1, \dots \dots, n \tag{1}$$

In fact, the weights will be estimated by minimizing a logarithmic regression function as shown in the formula (2) below and the fuzzy weights are deduced by the following developed formulas (3,4,5,6,7,8):

$$\ln(\alpha_i) \sum_{j\neq i}^{m} \delta_{ij} - \sum_{j\neq i}^{m} \delta_{ij} \ln(\alpha_j) = \sum_{j\neq i}^{m} \sum_{k\in D_{ij}} \ln(r_{ijk}) \qquad i = 1, \dots \dots, m \tag{2}$$

$$\ln(\alpha_{il}) \sum_{j\neq i}^{m} \delta_{ij} - \sum_{j\neq i}^{m} \delta_{ij} \ln(\alpha_{ju}) = \sum_{j\neq i}^{m} \sum_{k\in D_{ij}}^{m} \ln(r_{ijkl}) \qquad i = 1, \dots \dots, m \tag{3}$$

$$\ln(\alpha_{im}) \sum_{j\neq i}^{m} \delta_{ij} - \sum_{j\neq i}^{m} \delta_{ij} \ln(\alpha_{jm}) = \sum_{j\neq i}^{m} \sum_{k\in D_{ij}}^{m} \ln(r_{ijkm}) \qquad i = 1, \dots \dots, m \tag{4}$$

$$\ln(\alpha_{iu}) \sum_{j\neq i}^{m} \delta_{ij} - \sum_{j\neq i}^{m} \delta_{ij} \ln(\alpha_{jl}) = \sum_{j\neq i}^{m} \sum_{k\in D_{ij}}^{m} \ln(r_{ijku}) \qquad i = 1, \dots \dots, m \tag{5}$$

$$\tilde{\alpha}_i = \left(a \exp(x_{il}), b \exp(x_{im}), a \exp(x_{iu})\right) \; i = 1, \dots, m, \quad / \quad x_{il} = \ln(\alpha_{il}) \;\; x_{im} = \ln(\alpha_{im}) \;\; x_{iu} = \ln(\alpha_{iu}) \tag{6}$$

$$a=\frac{1}{\left(\sum_{i=1}^{m}\exp(x_{il})\sum_{i=1}^{m}\exp(x_{iu})\right)^{\frac{1}{2}}}\ ,\quad b=\frac{1}{\sum_{i=1}^{m}\exp(x_{im})} \qquad (7)$$

$$\tilde{\alpha}_i=\begin{pmatrix}\alpha_{il}\\ \alpha_{im}\\ \alpha_{iu}\end{pmatrix}=\begin{bmatrix}\frac{exp(x_{il})}{\left(\sum_{j=1}^{m}exp(x_{jl})\sum_{j=1}^{m}exp(x_{ju})\right)^{\frac{1}{2}}}\\ \frac{exp(x_{im})}{\sum_{j=1}^{m}exp(x_{jm})}\\ \frac{exp(x_{iu})}{\left(\sum_{j=1}^{m}exp(x_{jl})\sum_{j=1}^{m}exp(x_{ju})\right)^{\frac{1}{2}}}\end{bmatrix} i=1,..,m \qquad (8)$$

c) Develepement of the Decision Support Platform: Application of the Calculation Algorithm

In the present case, it has be appealed to three expert professors and present them the table below (table1) that shows the five used linguistic values (Very High, High, Equal, Low and Very Low) and theirs estimated values on fuzzy numbers (see table II). The experts are required to fill separately the comparison matrix of the six criteria (C1, C2, C3, C4, C5 and C6) (see Figure 2).

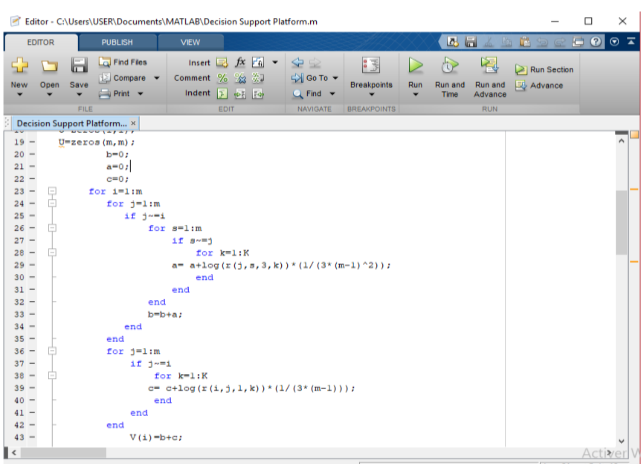
TABLE II. FUZZY NUMBERS VALUES OF LINGUISTIC VALUES

Linguistic Value	**Designation**	**Fuzzy Number Value**
VH	Very High	(7,9,10)
H	High	(6,7,9)
E	Equal	(3,5,7)
L	Low	(1,3,4)
VL	Very Low	(0,1,3)

In the order to make easier the calculation, we put α_{nl}=1 and α_{nm}=1 and the algorithm for resolving the three equations and calculating the normalized weights is developed on Matlab R2013a (see Figure 4).

The linguistic values and their correspondences on fuzzy numbers given by the three experts for comparing criteria are given in the table below (see table III).

From the results obtained by the developed platform, it can be noted that the weights of C1, C2, C3 and C4 are irrational fuzzy numbers that don't satisfy the condition "normalized lower value ≤ normalized mean value ≤ normalized upper value".



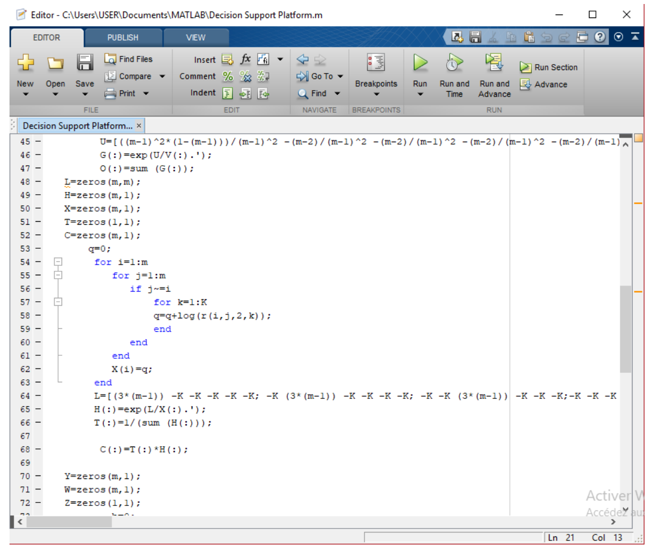


Fig. 4. The Implementation of the Decision Support Platform on Matlab R2013a.

The authors of [40] have already studied this point and criticize works of [38] and [39] in which normalized weights values that are derived from estimates based on ratio scales can generate an irrational ordering of fuzzy number's elements.

They tried to find the conditions on pairwise comparison values in order to get rational outcomes.

The condition is: $\alpha_{il} \le \alpha_{iu}$

That is equivalent to:

exp((-0.0014*V(1))+(0.009*(V(2)+V(3)+V(4)+V(5))));

XY=exp((0.0017*Y(1))+(0.0087*(Y(2)+Y(3)+Y(4)+Y(5)))+(0 0086*Y(6)));

YX=exp((0.009*(V(1)+V(3)+V(4)+V(5)))-(0.2514*V(2)));

YY=exp((0.0087*(Y(1)+Y(3)+Y(4)+Y(5)))+(0.0086*Y(6))-(0.2517*Y(2))) ;

ZX=exp((0.009*(V(1)+V(2)+V(4)+V(5)))-(0.2515*V(3)));

ZY=exp((0.0087*(Y(1)+Y(2)+Y(4)+Y(5)))+(0.0086*Y(6))-(0.2518*Y(3)));

WX=exp((0.009*(V(1)+V(2)+V(3)+V(5)))-(0.2514*V(4)));

WY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(5)+Y(6)))-(0.2517*Y(4)));

VX=exp((0.009*(V(1)+V(2)+V(3)+V(4)))-(0.2514*V(5)));

VY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(4)+Y(6)))-(0.2517*Y(5)));

UX=1;

UY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(4)+Y(5)))-(0.2517*Y(6)));

The execution of the algorithm on Matlab R2013a gives the fuzzy weights shown on the Table IV.

TABLE III. FUZZY PAIRWISE COMPARISONS OF PERFORMANCE CRITERIA

	C1 : Implementation	**C2 : Relevance**	**C3 : Exploitation**	**C4 : Granularity**	**C5 : Description & Organization (Structure)**	**C6 : Validation**
C1 : Implementation	(1,1,1)	L: (1,3,4) E: (3,5,7) L: (1,3,4)	H: (6,7,9) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	E: (3,5,7) H: (6,7,9) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)
C2 : Relevance	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	H: (6,7,9) E: (3,5,7) E: (3,5,7)	H: (6,7,9) L: (1,3,4) H: (6,7,9)	H: (6,7,9) VH: (7,9,10) E: (3,5,7)	L: (1,3,4) L: (1,3,4) E: (3,5,7)
C3 : Exploitation	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	L: (1,3,4) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)
C4 : Granularity	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H: (6,7,9) VH: (7,9,10) E: (3,5,7)	L: (1,3,4) L: (1,3,4) E: (3,5,7)
C5 : Description & Organization (Structure)	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{VH}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{E}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{VH}:\left(\frac{1}{10},\frac{1}{9},\frac{1}{7}\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H: (6,7,9) L: (1,3,4) E: (3,5,7)
C6 : Validation	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)

TABLE IV. ESTIMATED NORMALIZED FUZZY WEIGHTS OF DECISION CRITERIA

Criteria	**Estimated normalized weight**		
	$\boldsymbol{\alpha_{il}}$	$\boldsymbol{\alpha_{im}}$	$\boldsymbol{\alpha_{iu}}$
C1	0.0225	0.0275	0.0319
C2	0.0187	0.0308	0.0424
C3	0.1266	0.1310	0.1322
C4	0.1388	0.1468	0.1511
C5	0.4256	0.4483	0.4599
C6	0.1259	0.2252	0.3212

The table V below shows an example of the fuzzy pairwise comparisons matrix of the modeling methods filled by the committee. The comparisons are done based on the Criteria 1.

The computation of $\widetilde{\beta_{ij}} = (\beta_{ijl}, \beta_{ijm}, \beta_{iju})$, corresponding to the fuzzy weights of methods j (j=1,….,n) that are calculated under each criteria c_i (i=1,….,m) separately, is made in the same way by using the same formulas (2-8).

The tables VI to XI present the estimated fuzzy weights of modeling methods under criteria 1 to 6 (See Figure 5).

TABLE V. FUZZY PAIRWISE COMPARISONS OF MODELING METHODS UNDER CRITERIA 1

	M1: GRAI/GIM	M2: ARIS	M3: UML	M4: Petri Networks	M5: BPMN	M6: SCOR
M1: GRAI/ GIM	(1,1,1)	L: (1,3,4) E: (3,5,7) H:(6,7,9)	E:(3,5,7) L: (1,3,4) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	E: (3,5,7) H:(6,7,9) L: (1,3,4)
M2: ARIS	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$	(1,1,1)	E: (3,5,7) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	H:(6,7,9) H:(6,7,9) E: (3,5,7)
M3: UML	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	E: (3,5,7) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	H:(6,7,9) H:(6,7,9) E: (3,5,7)
M4: Petri Networks	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	L: (1,3,4) E: (3,5,7) E: (3,5,7)	H:(6,7,9) VH:(7,9,10) E: (3,5,7)
M5: BPMN	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H:(6,7,9) VH: (7,9,10) H:(6,7,9)
M6: SCOR	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{VH}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{VH}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{H}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$	(1,1,1)

TABLE VI. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 1

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0146	0.0533	0.0917
M2: ARIS	0.0508	0.0850	0.1179
M3: UML	0.1220	0.1349	0.1446
M4: Petri Networks	0.3989	0.5414	0.6736
M5: BPMN	0.1535	0.5527	0.7480
M6: SCOR	0.0062	0.0354	0.0645

TABLE VII. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 2

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0169	0.0504	0.0835
M2: ARIS	0.0566	0.0830	0.1080
M3: UML	0.1325	0.1345	0.1330
M4: Petri Networks	0.4186	0.5449	0.6603
M5: BPMN	0.1414	0.5650	0.7450
M6: SCOR	0.0055	0.0361	0.0666

TABLE VIII. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 3

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0080	0.0422	0.0761
M2: ARIS	0.0433	0.0691	0.0938
M3: UML	0.1337	0.1281	0.1190
M4: Petri Networks	0.5414	0.5823	0.6491
M5: BPMN	0.1193	0.6056	0.6887
M6: SCOR	0.0039	0.0271	0.0502

TABLE IX. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 4

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0063	0.0482	0.0900
M2: ARIS	0.0747	0.0850	0.0923
M3: UML	0.0878	0.1060	0.1219
M4: Petri Networks	0.5129	0.5921	0.6488
M5: BPMN	0.1258	0.4265	0.7240
M6: SCOR	0.0079	0.0290	0.0496

TABLE X. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 5

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0088	0.0388	0.0686
M2: ARIS	0.0704	0.0865	0.1007
M3: UML	0.1021	0.1078	0.1108
M4: Petri Networks	0.1378	0.3658	0.5902
M5: BPMN	0.1083	0.3829	0.6547
M6: SCOR	0.0056	0.0271	0.0484

TABLE XI. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 6

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0346	0.0626	0.0897
M2: ARIS	0.0809	0.0994	0.1157
M3: UML	0.1422	0.1464	0.1470
M4: Petri Networks	0.1979	0.2526	0.3021
M5: BPMN	0.1611	0.4578	0.7504
M6: SCOR	0.0082	0.0375	0.0666

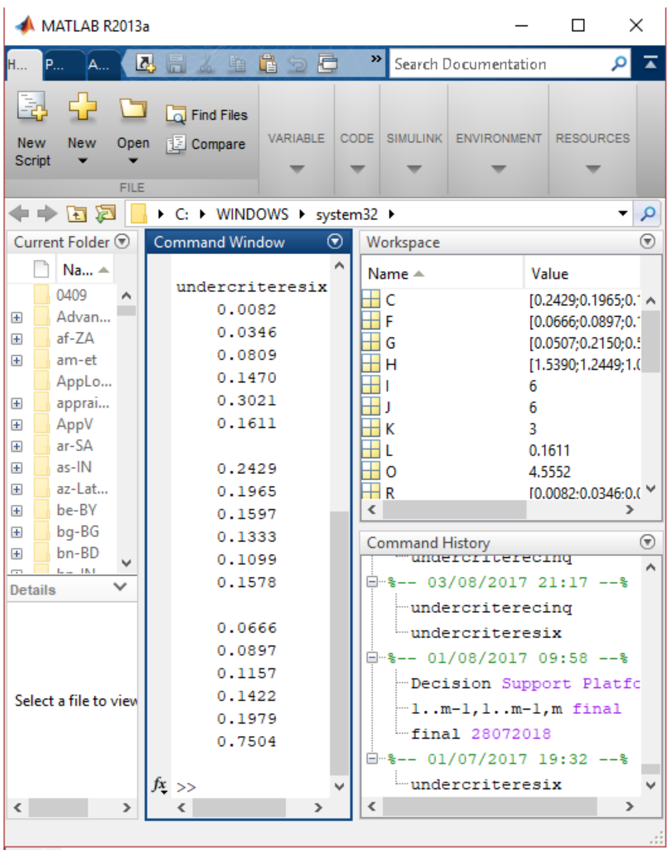


Fig. 5. Results of Weights Obtained by the Decision Support Platform.

Based to the obtained estimated fuzzy weights, the global weight is calculated for each method on the base of the formula N°1.

TABLE XII. FUZZY WEIGHTS OF MODELING METHODS UNDER EACH CRITERIA

Modeling method	Fazzy weighs
M1	(0,0106 0,0471 0,0905)
M2	(0,0582 0,0812 0,1082)
M3	(0,0957 0,1256 0,1464)
M4	(0,2401 0,4926 0,7000)
M5	(0,1050 0,4837 0,8295)
M6	(0,0052 0,0335 0,0843)

From the table above (Table XII) it is noticed that M5 (BPMN) and M4 (Petri Nets) have the best notations (see table XII). So, for this study case (the hospital supply chain), the modeling method adopted will be M5 (BPMN), M4 (Petri Networks) or a hybridization between them.

IV. CONCLUSION

The present work consisted, at the first, on giving a global view about the hospital supply chain and its global structure organization as it is given by the literature. Secondly, a literature review about the modeling methods which are used in the hospital supply chain was presented. The objectives of the modeling approach and its relationship with the performance analysis approach was subsequently justified. Afterwards, the research methodology that is adopted in this work was given for designing our decision support platform. In fact, a classification study based on the cross sorting methods and the fuzzy pairwise comparisons has been developed as part of a computer platform. For that, six criteria were developed in our case and were request from three experts to fill the comparison matrices concerning criteria and modeling methods by considering the hospital supply chain context. This contribution will facilitate the selection of the best modeling methods for our case and the best alternative in a general context. After several iterations, it has been concluded that BPMN and Petri Networks methods had the best notations. In our future work, we plan to improve and automate the decision support platform and to opt for the selected methods or a hybridization of them for modeling the cold supply chain in the hospital.

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