# Proposal of an Evaluation System for Monitoring Suppliers and Controlling Risks in the Hospital Sector

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***Abstract*— Today, the control of the purchasing function becomes a strategic tool of any hospital. Hence, hospitals are invited to create immediate value from identification and mitigation of risks in the upstream supply chain management. Among the problems encountered in the management of this chain are the evaluation and the monitoring of the performance of suppliers. The classification of the best-performing suppliers must be based on the analysis of risks that a hospital encounters when dealing with a supplier. Most experiments measure the risk according to the combination of two parameters, gravity and probability. Although these two parameters are subjectively determined, this implies the uncertainty and the imprecision of the risk value. Therefore, this paper presents an alternative approach for tackling such a problem starting with proposing a new system of evaluating suppliers, whose results will help to calculate objectively the risk associated to suppliers. Our paper is composed of four parts. The first one presents the literature review, while the second and third parts deal with the problematic definition and the proposed solution respectively, which are illustrated and validated through a case study in the fourth part. Finally, we conclude the paper with work perspectives.**

***Keywords*—** *Control, purchasing function, hospitals, supply chain management, best-performing suppliers*

## 1. Introduction

The purchasing function must generally be carried out in compliance with the following points: the quality level required, delivery of the desired quantities within the expected timeframe, under the best economic conditions of services [1].

This is the object of a new awareness; It constitutes an emergent function for all companies, and particularly, for all hospitals which are calling for a review of the organizational process. The aim is to master the process of the evaluation of suppliers in a competitive environment and to effectively ensure continuously the quality level of their benefits, in relation to the contract terms. In fact, during the selection of suppliers, it's the ability to meet all requirements of the contract and the level of risks that are assessed. Furthermore, the performance of the suppliers should be followed throughout the contractual relationship. Following several concrete problems cited by Moroccan hospitals and particularly the problem of non-compliance of medical devices, we are interested in the process of evaluating and monitoring of suppliers' performance. According to data obtained on medical devices in Morocco, we have found that there are 63 non-compliant consignments of 741 controlled medical devices in 2009 and 72 non-compliant consignments of 477 controlled medical devices in 2010 [2][33][39]. These statistics explain that the rate of non-compliance of medical products is increasing more and more over the years. Thus, it is necessary to develop a system of evaluation of suppliers; to help the hospital to well select its suppliers and also increase their capacity to respond to requirements of internal services as far as the terms of quality is concerned. It's in this perspective that our paper sheds light on, the evaluation and risk management of suppliers in the hospital sector.

## 2. Problem Statement

The problem treated in this paper can be tackled as follow: Every year, hospitals proceeds to two

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phases, started by suppliers' selection, then their evaluation. In fact, supplier selection is based on a study of three successive offers: administrative, technical and financial offer. Then after contracts have been awarded with selected suppliers, and once the orders are delivered, the service in charge accomplishes an evaluation of these suppliers' capabilities [3][34]. They rate them, and they track their performance based on a specific number of criteria, such as the respect of delay and the conformity of the product, etc. Providers who have a total less than 6 points are considered as failures, and the head of the service concerned, requests the direction to exclude them from participating in any market related to the hospital center for serious breach of commitments [3][35][37].The evaluation of suppliers according to the current system shows many points of failures that disrupt the upstream supply chain of hospitals. Firstly, it begins the selection process without taking into account the pre-sampling evaluation, because, from their point of view, it does not help to build confidence in the ability to meet the hospital requirements. In other words, there are no guarantees that assure the supplier selected on the basis of the sampling results, will retain the same level of performance after signing the contract and delivering the total order. Secondly, it does not allow to proceed to various comparative analyzes of overall scores obtained by suppliers. Thirdly, they don't examine their suppliers past performance, and evaluate the risk each provider poses to their supply chain. Therefore, the aim objective of our paper is to solve these problems, through a consistent system for assessing the level of performance of suppliers, which allows also determining the risk level that a hospital incurs in doing business with these suppliers. This risk element will be considered as a criterion to be among the inputs of a supplier selection process, which is based on the multiple sourcing strategy [4][36][38].

## 3. Literature Review

The articles published in the specialized journals in the areas of procurement and supply chain management, have allowed us to classify the different methods for evaluating suppliers according to four categories. Timmerman is among the first authors who proposed the weighed linear models which are based on the judgment and the experience of the evaluator [5]. In this category, many authors have proposed the AHP method which can be distinguished by its manner to determine the weights of criteria [6][7][8]. Kumar & al [9] have modeled the uncertainty and vagueness related to the values of the weights assigned to the criteria by the fuzzy set theory. Weber & al. [10] [11], Liu & al [12] have introduced the DEA method which allows developing a linear envelope to connect the criteria against those which present the possibility to calculate the efficiency of suppliers. Weber et al. [11] have firstly used the method of goal programming to select the suppliers and the DEA approach subsequently to assess their efficiency. The second category is based on the total cost to evaluate suppliers such as the method ABC (Activity Based Costing) [13], and the advanced method cost ratio [14] [15]. The third category based on the statistical models/probabilistic, such as the model Payoff Matrix which consists in defining several scenarios of the behavior of suppliers, and in each scenario, a note probable is associated; the supplier the more efficient is the one that has a stable note under different scenarios [16]. The VPA model (Vendor Profile Analysis) which takes a probabilistic function for each supplier vis-to-screws of each criterion and by simulation considers the behavior of suppliers [17]. The MNL model represents the probability of choosing an alternative from among a set of possible choices [18]. UT (Utility Theory) is proposed to study the subjective decisions of suppliers, describing them qualitatively [19]. FA (Factor Analysis) confirmed that the level of customer satisfaction and the performance of the company depend on the criteria taken into account in the process of selection and evaluation of suppliers [20]. ISM (Interpretive Structural Modeling) allows determining the relationship between the criteria and their importance levels to classify them into sectors [21]. CA (Cluster Analysis) allows grouping the suppliers according to the scores obtained for the criteria considered in the analysis in a number of clusters (groups) [22]. Other studies of segmentation of suppliers are also proposed in the literature. We can quote the study of Masella and Rangone [8] which consists to segment suppliers according to the type of relationship to which they belong. The empirical study of Svensson shows that the relations with suppliers evaluated are of four types [23]. Unlike the quantitative approaches presented previously, the tools of artificial intelligence are intended to integrate the qualitative

factors and human expertise in the evaluation and selection process for suppliers. We distinguished in this category several systems such as ES (Expert System) which is used to represent the knowledge and expertise that holds the purchasing professionals on the suppliers [24], and the CBR approach which uses the knowledge deducted from similar passed experiences on the suppliers [25]. The second step of a, evaluation system is to define a methodology to analyze and calculate the risks which is based primarily on the gravity of the consequences and the probability of occurrence [26], [27]. In our study, we propose an evaluation system that is based mainly on two principles: risk performance and past performance. The first one aims to evaluate each supplier by performing a benchmarking analysis and measuring the level of performance of services achieved by each supplier in two phases: a priori and a posterior evaluation (see Figure 1). And the second one consists to consider the supplier's past behavior. The objective of this system is to compare the level of performance achieved by each supplier before and after signing the contract, to make a comparative analysis between all suppliers, to perform a synthesis giving the overall performance of each of them after each delivery, and in a long term to have a number of reliable and trustworthy suppliers that also focuses on the principle of risk analysis.

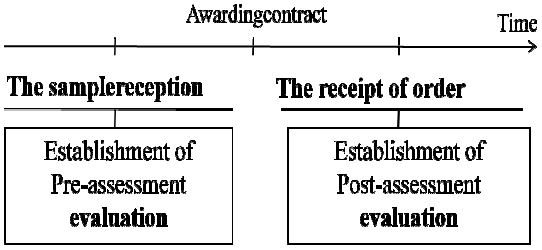


**Figure 1.** The two phases of the evaluation process

## 4. Proposed system

### 4.1 Purchasing process

To understand the input and output elements of the proposed evaluation system, we have positioned it in the cycle of the determined procurement process as shown in Figure 2. This system receives as input the suppliers with whom they have drawn up contracts, to measure the level of performance achieved before and after delivering the order, and will have to deliver as output the "Risk Performance", that characterizes each supplier, and help to rank current and potential suppliers. It will be considered as a criterion to be based in, in a multi-criteria decision support system for selection suppliers that we proposed in a previous work [38].

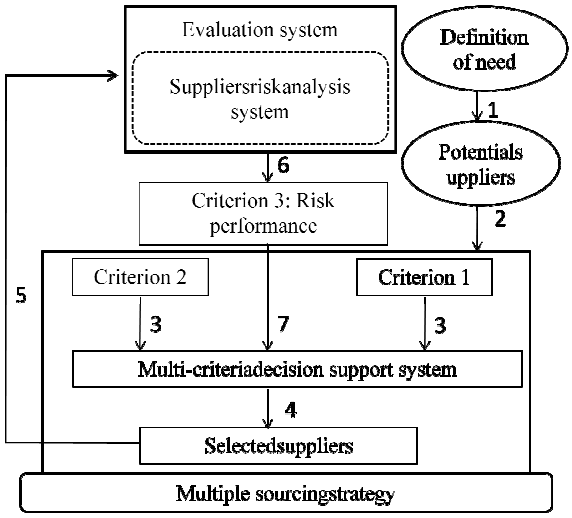


**Figure 2.** The positioning of the evaluation system

### 4.2 Suppliers evaluation system

The supplier performance measurement and evaluation system that we propose, characterizes objectively and continuously the level of performance of suppliers services in each contract. The figure 3 shows that it's mainly based on four principle approaches. For the rest of the paper we consider that:

- k represents the contract index, where $k \in \{1, N\}$, and N is the total number of contracts.

- i represents the supplier index, where $i \in \{1, M\}$, and M is the total number of suppliers.

- The Pre Assessment Evaluation ($NP_{Pre_{ik}}$) : It corresponds to the pre-qualification phase of supplier i in the contract k, to measure the ability of the supplier to meet requirements of the products quality through the assessment of sampling.

- The Post Assessment Evaluation ($NP_{Post_{ik}}$): it measures the actual performance of supplier i after delivering the order.

- The Pre Post Gap Performance ($PPGP_{ik}$): it's to actually check the delivery performed by the supplier i before and after signing the contract k and placing the order; Also to measure the gap

between the expected benefits and the reality of sourcing. $PPGP_{ik} = NP_{Post_{ik}} - NP_{Pre_{ik}}$

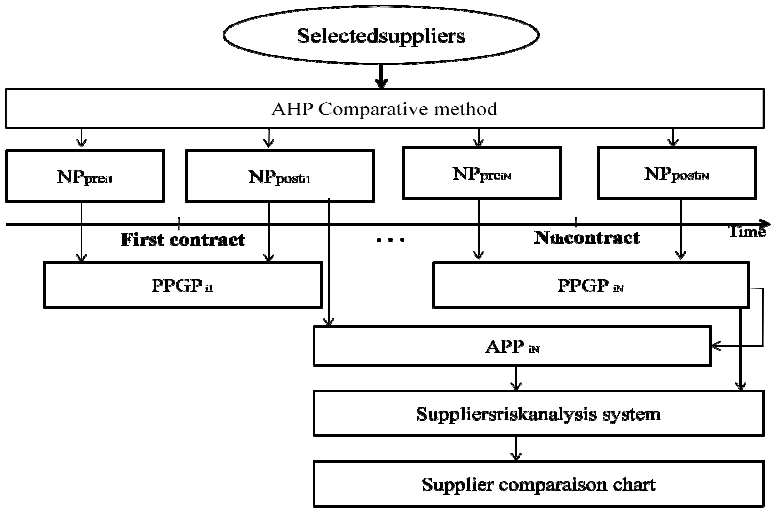


**Figure 3.** Proposed evaluation system information flow

- The Average Performance in the Past ($APP_{ik}$): it concerns the evolution of the performance level of supplier k achieved in the past since the first contract, to the one number k.

To perform the quality level achieved by each supplier through the sample reception and the receipt of order, we add to our system the AHP method, which is applied as an evaluation technique. It is a method that allows to systematically assessing the consistency of choices [28]. The key element of this method is the establishment of a well-built and well-understood hierarchy. In our case (As shown in table1) the top of the hierarchy is "quality", and the intermediate levels we offer are refined in the following sub-categories: Conditioning, labeling, packaging, packing and product conformity. The evaluator must perform binary comparisons between the different elements of the hierarchy before and after awarding contract.

**Table 1.** The evaluation technique for sample' suppliers

| | | Pre assessment evaluation for each supplier i ϵ {1,M} | | | | Post assessment evaluation for each Supplier i ϵ {1,M} | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | i=1 | i=2 | i=3 | i=M | i=1 | i=2 | i=3 | i=M |
| Sub-Categories j ϵ {1, 5} | Conditioning | $a_{11}$ | $a_{12}$ | $a_{13}$ | $a_{1M}$ | $b_{11}$ | $b_{12}$ | $b_{13}$ | $b_{1M}$ |
| | Packaging | $a_{21}$ | $a_{22}$ | $a_{23}$ | $a_{2M}$ | $b_{21}$ | $b_{22}$ | $b_{23}$ | $b_{2M}$ |
| | Labeling | $a_{31}$ | $a_{32}$ | $a_{33}$ | $a_{3M}$ | $b_{31}$ | $b_{32}$ | $b_{33}$ | $b_{3M}$ |
| | Packing | $a_{41}$ | $a_{42}$ | $a_{43}$ | $a_{4M}$ | $b_{41}$ | $b_{42}$ | $b_{43}$ | $b_{4M}$ |
| | Product conformity | $a_{51}$ | $a_{52}$ | $a_{53}$ | $a_{5M}$ | $b_{51}$ | $b_{52}$ | $b_{53}$ | $b_{5M}$ |

The resulting matrices are then in the form of matrices of comparison judgments, each judgment represents the dominance of supplier's performance on another, before and after awarding the contract. From these matrices we calculate the gap generated for each supplier i, in each contract k as defined in the equation (1).

$$\forall i \in \{1, M\}, \ \forall k \in \{1, N\},$$

$$PPGP_{ik} = \sum_{j=1}^{j=5} b_{ikj} - a_{ikj} \quad (1)$$

### 4.3 Risk analysis method

The second step of a performance evaluation system is to determine an adequate risk analysis process. Our objective in this section consists in defining a methodology to analyze and calculate the risks considered in the proposed evaluation system. A previous analysis was carried out on the draft European standard pr EN 9134 "Quality systems - Guidelines for the risk management of

the supply chain [12]. This draft standard deals with the risk management in aerospace organizations where supplier chains are complex and extensive. In the light of the different definitions [26][27][30], we note that the basic elements of the concept of risk are the terms "objective" or "prevision", "probability" and "consequences". The value of a risk R is obtained by the product of two parameters: the severity of the consequences G, and the probability of occurrence P. Each risk assessment criterion takes into account the sub-criteria associated to a weight according to their relative importance [27]. This method is based on an analysis scale which consists of assigning a grade to the item being examined, usually the higher the score is, the less the item is risky. Once calculated, the value of risk R is converted to a percentage representing a normalized criticality rate. This is a very simple and very intuitive criticality index with 0% corresponding to a non-critical situation and 100% to maximum dangerousness [26]. It is a simple, low-cost method, whose results cannot be considered as a reliable prevision for future behavior of suppliers, and present intuitive and subjective interpretation.

### *4.3.1. Suppliers risk management*

The supplier risk is the level of loss caused by the deterioration of the services provided by a supplier [26]. In our study we associate this level of risk to two principle elements: the pre post gap performance and the average past performance. The gap performance generated, decreases the level of confidence in the selected supplier, and increases the level of risk. This risk is influenced also by the average past performance of each supplier, which intent to encourage the hospital's policy to set out the supplier's past behavior. The risk is conventionally measured according to the combination of two main parameters as mentioned in the equation (2).

$$\text{Risk}_{ik} = \text{Gravity}_{ik} \times \text{Probability}_{ik} \quad (2)$$

According to our definition of risk, the gravity of consequences designates the level of loss caused by each supplier, and it's measured as indicated in the equation (3).

$$\text{Gravity}_{ik} = \frac{|\text{PPGP}_{ik}|}{\text{APP}_{ik}} \quad (3)$$

Measure and evaluate a risk is to know how to prevent events that could harm the organization [30]. In general, when it is necessary to quantify the probability of a risk, it uses a knowledge base which is connected to the time, because the risk is often calculated on a given period. In our approach we propose to calculate the probability of occurrence according to the total number of participations. See equation (4).

$$\text{Probability}_{ik} = \frac{\text{NP}_{ik}}{\text{T}_i} \quad (4)$$

Where:

- NP denotes : the number of times where $\text{PPGP}_{ik} < 0$

- T : Total number of participations

Consequently, the level of risk associated to each supplier is as defined in the equation (5).

$$\text{Risk}_{ik} = \frac{|\text{PPGP}_{ik}|}{\text{APP}_{ik}} \times \frac{\text{NP}_{ik}}{\text{T}_i} \quad (5)$$

Our paper will focus on the point of discussing the supplier risk in terms of criticality of orders.

### *4.3.2. Criticality of orders*

Identify and document the "criticality" of products and services obtained through the supply chain; will help to identify, prioritize and mitigate potential supply chain risks [31]. In our study we consider that each supplier could deliver one or many types of medical products, which creates the interest of criticality of orders. We define the criticality of orders as the degree of importance and the availability of the order for the hospital. These products are classified in the medical sector in 4 levels [32]. We characterize each level as indicated in figure 4, with a percentage risk associated to each product, with 25% corresponding to a product with a low degree of risk and 100% with a maximum risk level. Finally, the criticality of the order that must be delivered by each supplier becomes as determined in the equation (5).

$$\text{Criticality of order} = \sum \text{Criticality of product} \times \text{Quantity} \quad (5)$$

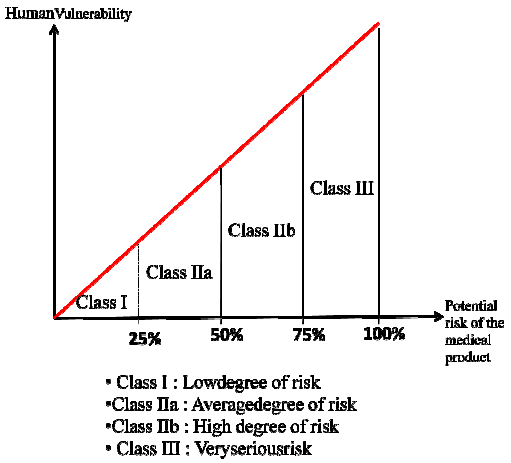


**Figure 4.** Different classes of medical products

*4.3.3. The variation of the function "Risk supplier"*

We intend to show the variation of the supplier risk function according to three variables: PPGP, APP and NP. We took randomly an example of one supplier, and we run the experiment by varying one of the variables while keeping the other two constants.

Supplier risk increases in three situations:

- When the average performance in the past decreases. It's clear that past performance is a good indicator of potential future performance. Our system intent to encourage suppliers that have a satisfactory performance rating in the past, and advise them to catch up the current mistakes. (**Figure 5**)
- When the difference of performance before and after delivering the order is increased, which means that the risk business with suppliers who have an unsatisfactory gap performance rating, is discouraged. (**Figure 6**)
- When the number of times where $NP_{Post} - NP_{Pre} < 0$ increases. The gap performance generated may be negative as it may be positive. In the first case, the supplier is automatically excluded from the list of the risky suppliers. In the second case, the negative gap generates a risky and dangerous situation. (**Figure 7**)

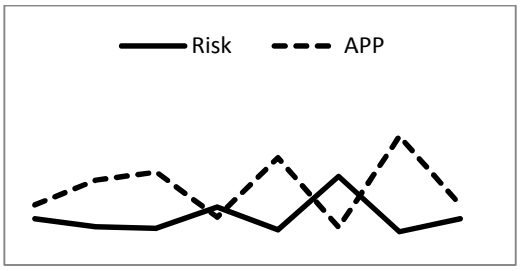


**Figure 5.** The risk supplier variation as a function of APP

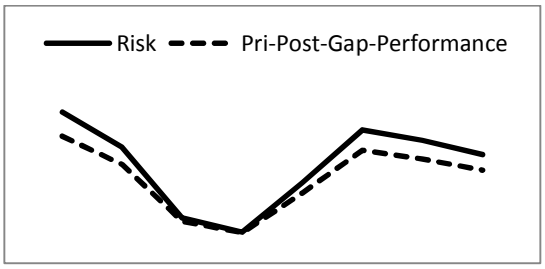


**Figure 6.** The risk supplier variation as a function of PPGP

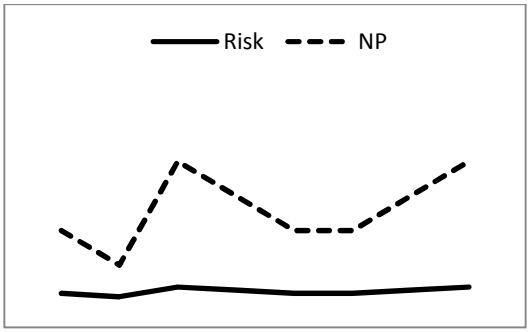


**Figure 7.** The risk supplier variation as a function of NP

## 5. Experiments

Our case study is a real application, where data are obtained from the hospital Ibn Sina in Rabat, Morocco. In TABLE 2, we have 14 selected suppliers, for each one of them we determined the criticality level of the order that he delivered. Thus, we have characterized each supplier by the predefined parameters since the first contract as depicted in TABLE 3.

**Table 2**. Criticality of suppliers' orders

| Supplier | Criticality of orders |
|---|---|
| F1 | 19% |
| F2 | 24% |
| F3 | 30% |
| F4 | 4% |
| F5 | 40% |
| F6 | 23% |
| F7 | 29% |
| F8 | 15% |
| F9 | 11% |
| F10 | 31% |
| F11 | 24% |
| F12 | 23% |
| F13 | 16% |
| F14 | 19% |

**Table3.** The practical case data

| | NP_Pre | NP_Post | PPGP | APP | T | NP | Gravity | Probability | Risk-supplier |
|---|---|---|---|---|---|---|---|---|---|
| F1 | 0,45236 | 0,36254 | -0,09 | 0,3652 | 5 | 2 | 0,246440307 | 0,4 | 0,098576123 |
| F2 | 0,14852 | 0,13245 | -0,016 | 0,28652 | 3 | 2 | 0,055842524 | 0,666666667 | 0,037228349 |
| F3 | 0,33265 | 0,32125 | -0,0114 | 0,1826 | 2 | 1 | 0,062431544 | 0,5 | 0,031215772 |
| F4 | 0,14258 | 0,12652 | -0,01606 | 0,1425 | 2 | 1 | 0,112701754 | 0,5 | 0,056350877 |
| F5 | 0,5274 | 0,31256 | -0,21484 | 0,2365 | 5 | 2 | 0,908414376 | 0,4 | 0,363365751 |
| F6 | 0,4582 | 0,3741 | -0,084 | 0,322 | 5 | 2 | 0,260869565 | 0,4 | 0,104347826 |
| F7 | 0,24533 | 0,2365 | -0,00883 | 0,6352 | 7 | 2 | 0,013901134 | 0,285714286 | 0,003971752 |
| F8 | 0,12665 | 0,10254 | -0,024 | 0,741 | 12 | 8 | 0,032388664 | 0,666666667 | 0,021592443 |
| F9 | 0,63215 | 0,52631 | -0,106 | 0,5215 | 10 | 5 | 0,203259827 | 0,5 | 0,101629914 |
| F10 | 0,92513 | 0,78521 | -0,13992 | 0,4231 | 7 | 4 | 0,330701962 | 0,571428571 | 0,18897255 |
| F11 | 0,74521 | 0,62531 | -0,12 | 0,6325 | 6 | 3 | 0,18972332 | 0,5 | 0,09486166 |
| F12 | 0,12365 | 0,09 | -0,034 | 0,4213 | 7 | 6 | 0,080702587 | 0,857142857 | 0,069173646 |
| F13 | 0,5213 | 0,4125 | -0,109 | 0,326 | 5 | 4 | 0,334355828 | 0,8 | 0,267484663 |
| F14 | 0,63215 | 0,42365 | -0,2085 | 0,4521 | 6 | 4 | 0,461181155 | 0,666666667 | 0,307454103 |

### *5.1. Suppliers comparison*

Once the supplier risks and the criticality of orders are determined for a set of 14 suppliers, they can be compared. The objective is to identify suppliers with the lowest combined risks. The chart indicated in the **figure 8**, is a visual way to classify suppliers according to both types of risk (supplier and order). While the chart presented in the **figure 9** shows the variation of the risk supplier in terms of the Pre Post Gap Performance and the Average Performance in the past. We can take as an example the comparison of the supplier F13 and F8, who are both considered as "risky" suppliers for future contracts, they are responsible to deliver a command almost of the same criticality, although F8 showed better efficiency compared to F13. Therefore, F8 would be the recommended choice for these products section. Unlike suppliers F5 and F14, who made a drop in performance going from 0.527 to 0.312 and 0.632 to 0,423 respectively, this gap is approximately the same, although F14 is considered the less risky because of having a good performance in the past compared to F5. These results show that this system intent is to help the decision maker in the future, to avoid the "risky" supplier relationship, and to compare each supplier's risk value, against the criticality of the purchase order.

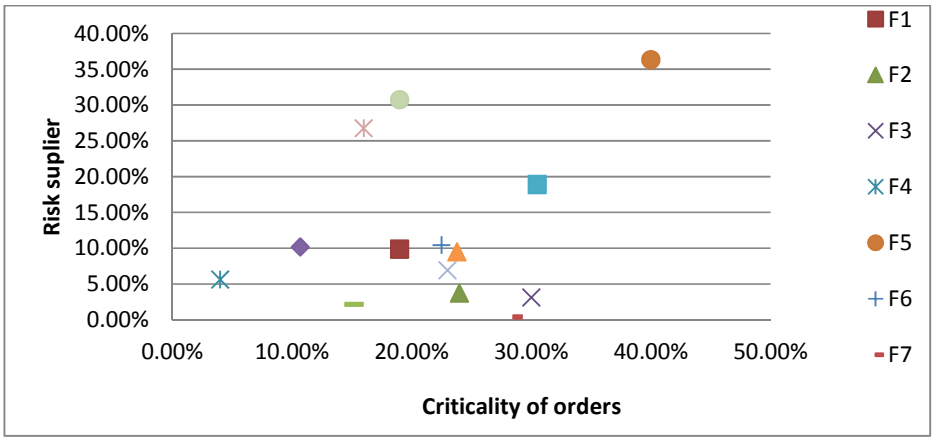


**Figure 8.** Supplier's comparison chart

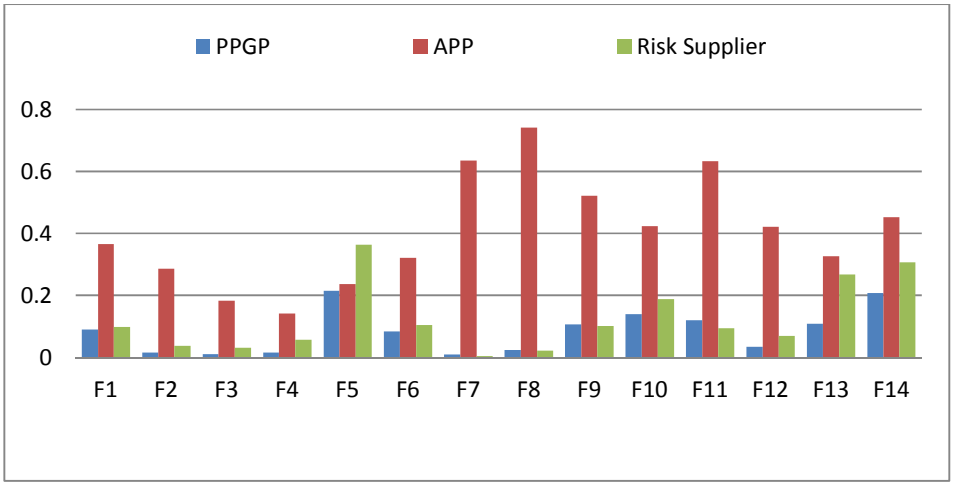


**Figure 9.** Supplier's parameters variation

## 6. Conclusion

The evaluation process has seen a new tool: The calculation of the criticality of the risk associated to suppliers based on the performance results before and after placing the order. The strengths of the proper functioning of the evaluation process of suppliers according to our system is to improve firstly the quality performance of suppliers, secondly to ensure the satisfaction of the internal services in term of compliance of medical products, and thirdly to manage the supplier relationship while taking into account the sustainable development strategy for the suppliers which are the most critical. In our future work, we will further improve this evaluation system by integrating an efficient sampling method for suppliers.

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