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A CBR approach based on ontology to supplier selection

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Abstract Most previous research categorizes supply chain management (SCM) into the following three major parts: purchasing, manufacturing, and distribution. In the purchasing process, supplier selection represents a crucial step for enhancing firms' competitiveness.An increasing number of researches have been devoted to the development of different methodologies to cope with this problem.The majority of research explores the difference in the set of criteria for supplier selection. They used famous methods for selection such as AHP (Analytic Hierarchy Process); ANP (Analytic Network Process); DEA (Data Envelopment Analysis);TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). Thus, this paper presents a CBR (Case Based Reasoning) approach in the context of supplier selection decision making.

Keywords Supplier selection · Ontology · Experience Feedback (EF) · CBR

1 Introduction

The best use of human resources is not limited only to the selection of the right knowledge in the right place at the right time, but also to find the experienced actor. This has the advantage of having a better control of

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activities. Hence, competence is not static anymore, but is rather dynamic over time, depending on the experience of actors. Problem of allocation or selection has been addressed in several research works. Among these, one can mention the use of fuzzy logic approach for modelling skills. Another approach is interested in scheduling preventive maintenance tasks on identical resources [1]. There is also another axis that focuses on the dynamic insertion of tasks in an ordinary scheduling for resources with one competence only [2]. However, in production system, many studies are interested in the scheduling of human resource activities [3] where few approaches take into account the skill levels of resources [4]. One can still note the work of Gruat La Forme [5] who take into account the skill levels through a variable productivity rate in a multi-criterion problem.

In the field of logistics, several research works, dealing with decision support systems for the problem of supplier selection, have been achieved. In this context, in order to meet the company's requirements, a selection model based on the exploitation of domain ontology to build a case base is proposed in this article. This case base generates new knowledge about competence according to the information gathered within the company. Such application supports the use of Experience-Feedback (EF) as a tool to aid the supplier' selection in order to have a better planning purchasing process.

2 State of the art

Lima Junior [6] presented a comparative analysis of fuzzy TOPSIS methods (Fuzzy Technique for Order of Preference by Similarity to Ideal Solution) and Fuzzy AHP (Fuzzy Analytic Hierarchy Process) applied to the problem of Supplier Selection (SS). The comparison was based on several factors, such as the adequacy to changes of alternatives or criteria, agility in the decision process, computational complexity, adequacy to support group decision-making, number of alternative suppliers and criteria, and modeling uncertainty. In 2016, Bruno [7] proposed an integrated model, which combines two main approaches proposed in the literature, and which deals with the supplier selection (SS) problem, analytic hierarchy process (AHP) and the fuzzy set theory (FST).
There is a different overview about criteria for supplier selection since the beginning of this area. A review is given by Weber *et al.* [8], covering 74 articles on selection of suppliers. The authors observe that aspects related to price, delivery, quality and production capacity are the criteria most often considered in the literature.
However, the importance of criteria changes; depending on the context industrial considered as presented in [9]. Where are the criteria classified as: logistics, technology, business and business cooperation. The aim was to create a model that distinguishes between qualitative and quantitative criteria.
An assignment is easy to achieve, but a good one is not always possible. Most of the above-mentioned studies are based on price and quality as a primary

factors, in a problem of supplier assignment. Furthermore, as it is difficult to give precise numerical values to the concept of competence, almost all authors use fuzzy logic, initiated by Zadeh [10]. This is considered as the most appropriate theory in expressing the inherent imprecision. Unfortunately, to realize this theory, one needs to choose some rules of inference. This choice is neither exhaustive nor definitive, and provides a rough quantitative value that cannot be considered as accurate and reliable. Other studies are based on competence with a static level that is affected either directly or through fuzzy logic.
In summary, from the literature review presented above, it can be concluded that supplier selection criteria change over time, depending on the political, economic, social, and environmental characteristics of the business.
In light of the remarks of the above literature, one can easily notice that most systems focus on different criteria and lost the aspect of supplier competence. Thus, the objective of this article is to show the effectiveness and benefits of introducing the concept of dynamic competence for selecting supplier in a purchasing process. In other words, it is about assessing competencies in relation to past experience. This implies a mechanism that ensures the flexibility and adaptability of the process.

3 Proposed supplier selection approach

In present work proposed to develop a decision support system. This approach focuses on the selection of supplier according to their level of competence. Competence has a dynamic character due to its evolution over time depending on the supplier's experience.

3.1 Knowledge Base and FOMES ontology

A particular attention needs to be directed towards ontology. Ontology allows exchanging information and knowledge between actors in the same semantics [11],[12].The use of ontology is due primarily to three factors: (i) the development of domain ontologies, (ii) the availability of software tools for building, editing and deployment of ontologies. (iii) the existence of a set of ontological model formalisms (OWL, PLIB, etc.) which have significantly contributed to the emergence of ontology-based application.
Several definitions of ontology are discussed in the literature. The best known is the one proposed by Gruber, who defined ontology as a 'formal and explicit specification of a shared conceptualization'[13]. In our work, we used FOMES (Feedback-CBR Ontology for Maintenance Expert Selection) [14]; it is extended form of the ontology IMAMO. (Industrial Maintenance Management Ontology)[11]. FOMES is used to include all types of knowledge in the form of a set of concepts in the supplier area as well as the dependencies existing between them. The Protégé 4.1 ontology editor was used to extend FOMES.
Our model was extended to classes and datatypes in FOMES, so as to add

some proprieties and change certain relations between the concepts. For example, the Data Type *Level Commitment* is an attribute that is added to the concept SUPPLIER. It shows the level of commitment of a supplier. It is a new criterion that expresses the dynamic expertise through experience. The concept *Agenda* was added, and connected with the SUPPLIER class, to help obtaining the schedule of every SUPPLIER. This is crucial for the best management of resource during a purchasing. *Level* data type is another attribute added to the class SKILL. This attribute allows determining the skill level of each actor.

3.2 Supplier selection process

The Supplier Selection operating mechanism is based on the dynamic assessment of the competence of a supplier, while paying more attention to the analysis of his past experiences. In such situation, the management of experiences focuses mainly on the practical knowledge resulting from each selection offer solving and on its modelization, i.e. specific knowledge linked to a purchasing activity, in a particular context. This implies an experience feedback process corresponding to a cycle of actions involving two main phases (Fig.1) which are the capitalization process (acquisition of experience and memorization), and the operating process (reuse and adaptation) [15].

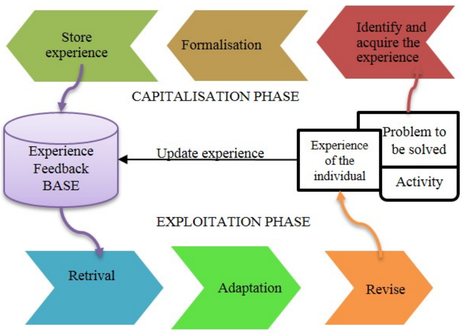

Fig. 1: Cycle of experience feedback [15]

The capitalization phase aims to identify and extract knowledge. Therefore, this knowledge has got to be formalized and structured in the form of experience; in order to make it easily accessible and reusable in solving new problem (in our study problem is mean new offer).The exploitation phase consists of finding the useful experience in the case base (experience base), adapt it to the problem to be solved and implement the solution from the experience base. Among the methods developed in the framework of engineering knowledge for solving problems based on experience, the method of Case-Based Reasoning

(CBR), which is the most widely used in selection problems, was chosen for our work. In this method, elements of experience are expressed in the form of "cases".
Generally speaking, the CBR cycle may be defined by the following phases:

– **Retrieval phase**: The most relevant and similar cases are recovered from the case base when a target problem (or a new case) appears.

– **Reuse/adaptation phase**:It consists of building a solution to the problem of the target case. This solution is inspired by the most similar source case solution.

– **Revise phase**:It tests the proposed solution in the real world or in a simulation and, if necessary, revises it in order to have a better solution.

– **Retain phase**: It phase aims at storing the result obtained as a new case in the case base; this is done after validation of the solution.

Each phase of the CBR cycle is detailed in what follows.

3.2.1 Elaboration

The user (manager) must enter the new case using the same representation and level of detail of the cases stored in the case base. A case base is a memory which contains a collection of cases used in the context of the CBR methodology which aims to perform a reasoning task. In general, a case in CBR consists of two essential parts, i.e. the problem and the solution. The case is represented as a set of descriptors. FOMES will be exploited in order to represent the case model previously investigated in the present work. First, a concept called Case was created; it puts together all the cases of the base. That concept is related to three concepts, i.e. ***"Problem"***, ***"Solution"*** and ***"Evaluation"***, using the object properties *"has problem"*, *"has solution"* and *"has evaluation"*, respectively. An Object property named *"has GeographicalLocation"* relates the concept ***"Problem"*** with ***"GeographicalLocation"*** which records the different zones and subzones of firm, with the two Datatypes*zone* and *subzone*. The different datatypes of the need, such as the *quantity, price, urgency of the order*, etc., are stored in the ***"Need"*** class. The equipment available is in the ***"Equipment"*** class, and each piece of equipment is part of a group of equipment (***Equipmentgroup*** concept), with the Object property *"belongsTo"*. Each Equipment group is linked to the concept ***"Domain"*** by an object property *"belongsTo"*.
Thus, the ontology stores information about the solution of a case in the concept ***"solution"***. When a new order is established, the search for a supplier is launched and it is stored in the class ***"Need"***. This task is performed by supplier, who are found in the class ***"supplier"***, which is defined by a set of Datatypes such as *Supplier-ID, name, address, commitment level*, etc. An Object property *"has Skill"* relates the skill in a specific domain to the concept

Supplier. To manage the availability of each Supplier, the object property *"has Agenda"* must be developed.
Finally, the ontology contains a concept called ***"Evaluation"***. This class contains information about the assessment of the case solved. Therefore, the concept Evaluation has a Datatype *"status"* (success / failure), *"coast"* (cost of invoice) and *"time"* (delivery time). The Object property *"relatesTo"* is associated with each Supplier evaluation.
In literature, there are two types of cases in case base; i.e. the source case and the target case. The source case is one in which the "problem" and "solution" parts are clearly indicated. Therefore, it is a case where one should be inspired to solve a new problem. However, the target case is a case that appears at the occurrence of a new problem, whose solution part is not indicated.
In our case base, a case describes a situation that is need to purchase an item. That case is determined by a list of descriptors, divided into two groups, i.e. one concerns the problem and one the solution.
The problem field consists of eight descriptors reflecting the description of a localized firm divided in two sub-parts; i.e. the Geographical Location that determines the zone and sub-zone of firm need (descriptors ds1 and ds2, respectively) and the need part, which consists of the Equipment marque, Equipment Type, estimated price, quantity, quality, the degree of urgency "it mean the limited time that the firm is needed the equipment" (descriptors ds3, ds4, ds5, ds6,ds7 and ds8, respectively). However, the solution field is composed of two descriptors that describe selected supplier (descriptor ds9). This formalism has been designed and developed in order to take into account all possible relationships between the constraint of firm and supplier.
Considering all these specificities, it becomes possible to schematically represent the structure of the case, as shown in Table 1.

Table 1: Case Base

Case	Context								
	Geographical		Need Part						Solution
	Zone	Sub Zone	EQP Marque	EQP Type	Estimated Price	Quantity	Quality	Emergency level	Supplier-ID
	ds1	ds2	ds3	ds4	ds5	ds6	ds7	ds8	ds9

In summary, in this section, the combination of the descriptors was defined so that any problem can be analyzed. The manager determines the first eight descriptors of the target case; they are also descriptors of the source case named (dt1 ... dt8). From there, there will be an elaborated target case which allows us to go to retrieve the source cases most similar to that target case.

3.2.2 Retrieval

The purpose of the Retrieval step in case-based reasoning (CBR) is to recover one or more cases that can be reused in the context of a new problem. As it is generally unlikely that the case base contains a problem already processed, which exactly matches the new problem, the concept of similarity is therefore used. The similarity measure allows calculating the similarity between the descriptions of the two problems (source and target). In general, similarity can be of three types: (1) surface similarity, (2) derivative similarity and (3) structural similarity [16].
In the literature, many similarity measures, based on the taxonomic structure, have been illustrated. For example, the measure proposed by Wu and Palmer [17] and more recently that of[18–21] can be mentioned. It has been decided, in the present study, to use the similarity measure, proposed by Haouchine [22], and based on the information resulting from the FOMES ontology. That measure is divided into two steps:

– **Retrieval measure (RM)**: To calculate the Retrieval measure (RM), it is possible to use the same principle of measure as that of Haouchine [22], by modifying the expression of that measure, which is the combination of various measures and results using formula (1):

$$R_M(S_1, T) = \frac{\sum_{i=1}^{P} sim(ds_i^{value}, dt_i^{value}) + \sum_{i=p+1}^{m} sim(ds_i^{value}, dt_i^{value})}{\sum_{i=1}^{j} sim_{presence}(ds_i^{value}, dt_i^{value})} \tag{1}$$

.
where S1: First source case; T: Target case. p: represents the number of location descriptors, m: is the number of need-part descriptors (ds3,ds4,ds8),

$$ds_i^{value}, can\ have\ two\ possible\ values\ :$$

$$sim(ds_i^{value}, dt_i^{value}) = 1\ when\ ds_i^{value} = dt_i^{value}$$

$$= 0\ when\ ds_i^{value} \neq dt_i^{value}$$

In case the descriptors are not all filled, a presence similarity measure is defined. It will take into account the presence of descriptors in the case.

$$sim_{presence}(ds_i^{value}, dt_i^{value}) = 1\ if\ information\ is\ present\ both\ in\ S_1 and\ T$$

$$= 0\ if\ information\ is\ not\ present\ in\ one\ descriptor$$

From the calculation of the overall similarity, a set of cases can be chosen which will take into account only the highest value.

– **Adaptation measure (AM)**: In order to select the most adaptable source case, among the retrieved cases, it was necessary to develop the "adaptation measure". This measure takes into account the urgency level by giving it a high priority. This weight is important in determining the urgent case. Indeed, a high weight is assigned to the top level of urgency α . The presence of the descriptor value can also be taken into account, as this facilitates the adaptation.

$$A_M(S_1, T) = \frac{\sum_{i=P+1}^{j=m-1} sim(ds_i^{value}, dt_i^{value}) + sim(ds_m^{value}, dt_m^{value}) \times \alpha_m}{sim_{presence}(ds_i^{value}, dt_i^{value})} \tag{2}$$

Where: p represents the number of localization descriptor.
m: represents the number of Need-part descriptors.

$$\alpha_m \textit{ is the associated weight according to the urgency level.}$$

$$\text{if} \begin{cases} ds_m^{value} = dt_m^{value} = High \rightarrow \alpha_m = 2^2 \\ ds_m^{value} \neq dt_m^{value} = (High\ /Low\ or\ Low/High) \rightarrow \alpha_m = 2^1 \\ ds_m^{value} = dt_m^{value} = Low \rightarrow \alpha_m = 2^0 \end{cases}$$

Therefore, the source case with the largest value of the adaptation measure, among the retrieved source cases, will be the candidate selected for the next step.

3.2.3 Adaptation (Reuse)

The second step in the CBR cycle is the reuse or the adaptation; this leads to propose a solution to a new problem from the solutions in the retrieved cases. In most situations, the authors simply use the substitution or transformation [16]. It is rarely possible to use a solution exactly as it is recorded. This happens if the new problem situation is not too different in essential aspects from the nearest neighbor selected from the case base. Then the recommendation is to adapt the recorded solution before reusing it to best suit the new problem. In some particular contexts, some approaches are proposed in the literature; they are based on the dependency relations (or correlative value) between the problem space and solution space of a given experiment [23]. Adaptation can be performed on different levels of granularity. In the present work, the solution part describes supplier, therefore the question is how can we assign a supplier in a new problem? Another question is who can be selected to the new problem? In this context, no problem if there is only one retrieved solution. In the present work, it is supposed that there are several retrieved cases. So, to generate a new solution, based on a previous solution, a specific approach is presented. From all the recovered cases, the proposed adaptation is based on Ranking with respect to case evaluation. This consists of selecting cases according to the evaluation criterion. Evaluation is a concept in FOMES ontology, which defines assessment of the case solved according to three criteria, which are time, cost, and an indicator that indicates whether the problem is resolved with success or no. Each criterion is represented by a DataType, i.e. delivery time, coast and state, respectively. The last criterion allows us to have a new list of cases (all cases that supplier has been delivered in the best condition). In order to achieve this goal, a description language is used to make rankings according to the queries.

3.2.4 Revise and Retain

During the revision phase of the CBR cycle, the solution proposed in the end of the adaptation phase is evaluated. This evaluation concerns the testing of the solution proposed in the real world. So, the revision phase consists of eventually continuing the development of the target solution, if necessary. Therefore, if supplier/new problem assignment is not satisfactory, then it is corrected. In the present situation, these corrections can be made by the manager who may give his own assessment relative to the selection provided via the CBR system. The case, reviewed and validated, can be applied; it becomes a new experience that must be capitalized in the case base.

4 Illustrative example

In this section, our approach is applied to a real example. One starts by identify the information resources and knowledge. These resources involve the history of documents about purchasing management, as well as the expertise of the domain. Our goal is to identify different equipment and constraint in the company. This statistical study allows collecting the information needed to enrich the FOMES ontology. Therefore, the attributes of the case are produced from these data. An attempt was made to reduce the number of descriptors in order to get a simpler table that meets our requirements.
Therefore, a case base was built, from which a sample of 31 cases was considered. For instance, case 1(or source 1) is interpreted with its problem and solution part see table.

Table 2: Example of source and target case

Case	Geographical Location		need-part						solution
	ds1	ds2	ds3	ds4	ds5	ds6	ds7	ds8	ds9
Source S1	TLE	ZI	BMW	INJECT	2M	900u	Medium	Hight	Supp-ad3
Target T1	TLE	MG	W	INJECT	1M	600u	LOW	Hight	-

The principle of similarity calculation is applied to our case study, according to the approach proposed in Section 3.2.2.

4.1 Retrieval measurement (RM)

First, a target case is proposed to simulate the calculation of similarity table 2. For example, the calculation of local similarity for all descriptors, between the target T1 and source S1, is performed as follows:

$$\mathrm{R}_M(s_1,T) = \frac{(1\times1)+(0\times1)+(0\times1)+(1\times1)+(0\times1)+(0\times1)+(0\times1)+(1\times1)}{8} = 0,4$$

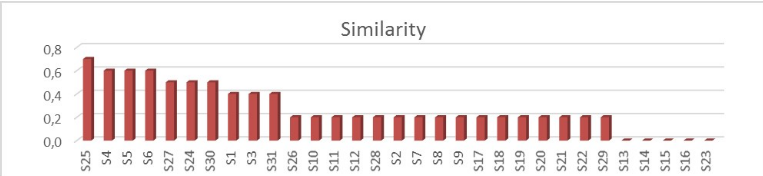

Fig. 2: Results of similarity calculations

All local similarities, between the source cases and Target, are calculated using the same formula (see summary of calculations in Fig. 2).
According to the results obtained, the retrieval source cases, which have the largest value of similarity measure (S25, S4, S5, S6,..., S31), are selected for the adaptation measure step. A total of 10 cases are selected.

4.2 Adaptation measure (AM)

Let's move to the second phase of similarity calculation. Remember that the objective is to choose, among the recovered cases, the closest one to our target case, which will be the candidate selected for the second stage of the CBR. Descriptor "ds8" is selected to be given a priority, by imposing a heavy weight. Because it is an urgent case, a quick decision selection in the solution space is needed.

Now the adaptation measure of the source cases most similar to target is calculated:

$$\mathrm{AM}(s_{25},T) = \frac{(0\times1)+(1\times1)+(0\times1)+(0\times1)+(0\times1)+(1\times2^2)}{6} = 0,8$$

Applying the calculations to our cases, the following results are obtained:

Table 3: adaptation mesure

	S25	S4	S5	S6	S27	S24	S30	S1	S3	S31
AM	0,8	1,8	0,8	0,4	1,6	1,3	2	1,4	1,9	1,6

One can note that the source cases S4, S27, S24, S30, S1, S3 and S31 have the different similarity measures; they are superior to 1. Moreover, cases S25, S5 and S6 have an adaptation measure less than 1. Therefore, the high degree of adaptation measure (AM) expresses the cases of perfect satisfaction; they will be selected for the adaptation phase.

4.3 Adaptation

The purpose of the present study is to improve the selection process through the adaptation phase. It focuses firstly on a method based on ranking through SPARQL queries, secondly on OWL API, a high level Application Programming Interface (API) for working with OWL ontologies.
Considering the results from the Retrieval step, the first step of ranking with respect to 'Evaluation' is applied. The suppliers must be recovered using the filter which is used in the SPARQL query to return only supplier who participated in the cases stored and evaluated successfully. With this query, all the suppliers are recovered and put in a list.
When this list is recovered, by using Monte Carlo simulation, the distribution of all possible outcomes of suppliers' ranking is generated by analysing a model several times, each time using input values selected by chance from the probability distributions of the factors (time and cost). Due to the different factors and because many values that each of these factors can take, there could be an infinite number of possible combinations that may affect supplier's selection.
The Monte Carlo simulation was run for 1000 iterations so as to generate the stochastic dataset for data mining. Each data record generated from Monte Carlo simulation, represents one evaluation of case solution, is classified into one of five groups Supplier1, Supplier2, Supplier9, Supplier10 and Supplier12 (suppliers' list obtained from the first step of ranking). The cost and time were generated based on a uniform distribution.

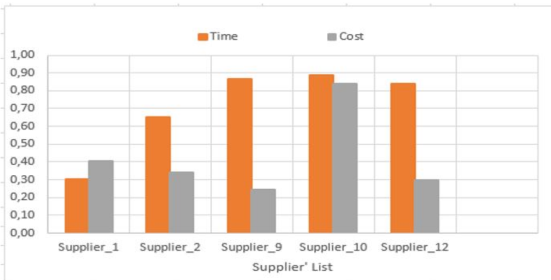

Fig. 3: Time and Cost calculations

According to the lot of-fold, the training dataset was randomly divided into five disjoint subsets (the five supplier). Fig.3 shows mean time and mean cost of each supplier. Based on the results obtained, when comparison is made between different supplier, it can be found that the first one in the list is supplier with the minimum value of time equal to (0,30). One notes that time and cost has higher values affected to Supplier10, that mean he is the last one in supplier list, because he has the higher time and cost compared with others.

5 Conclusion

The issue of selecting the actors involved in the conduct of industrial processes is highly justified by a research diversity which focuses on the combined integration of different criteria, in problems of allocation, planning and scheduling. This emancipation has led to a change in the formulations of these problems. The research work, presented in this article, taken into account that different criteria are not always sufficient to meet the resolution requirements for purchasing problem with respect to time, cost and efficiency. As previously explained, other additional criteria are required to improve the selection process.

Furthermore, new criteria, such as the dynamic skill, should be integrated through experience. A methodology of experience feedback processes around the reasoning from cases should be considered. This methodology proposes an approach, developed in four phases, which allows capitalizing on experience.

Our proposal was structured to include three elements, which are the use of: (i) ontology FOMES as support for the domain, (ii) EF approach for the selection of supplier, and (iii) case-based reasoning (CBR) as a problem solving technique which is based on adapting the solution from past experiences. In this article, a formalization of the experience was developed. To recover the most appropriate information for the current case, a method of guided adaptation recovery was used and two similarity calculations were developed. To refine the selection of supplier, a ranking, based on the SPARQL query language, was developed in the third stage of the CBR cycle.

This work presented a sample application that allows integrating the proposed approach in situations that are similar to those encountered in industry.

In the end, some real contributions of this study should be mentioned. Since this is an experimental method, it must be validated through a large-scale application that could be validated for any domain. This method has been compared with other techniques related to problem selection. For example, Fuzzy TOPSIS and Multi-criteria decision making (MCDM). Which will be the subject of future research.

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