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Supporting decision-making in service supplier selection using a hybrid fuzzy extended AHP approach

A case study

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Abstract

Purpose – Service supplier selection is a multi-criteria decision-making (MCDM) problem assuming a strategic role for the competitiveness of high-tech manufacturing companies. Nevertheless, especially for service quality evaluation, there is little empirical evidence of the practical usefulness of MCDM methodologies. Aiming to cover this gap between theoretical approaches and empirical applications, the purpose of this paper is to propose a fuzzy extended analytic hierarchy process (FEAHP) approach for service supplier evaluation.

Design/methodology/approach – A hybrid approach which combines some of the strengths of the analytic hierarchy process (AHP) and of the fuzzy set theory is presented, as organized into five steps. A case study is used to evaluate the applicability in a real company context.

Findings – The usability of the approach is demonstrated in an aerospace company for solving the supplier selection problem of a business software whose applications are still in infancy: a Test Data Management System (TDMS). The illustrative application contains both "general" criteria to be used for other service supplier selection contexts as well as service-specific criteria related to software selection.

Research limitations/implications – Even if the application regards the selection of a software supplier, the methodology can be generically extended to other services' selection in complex manufacturing industries through the personalization of some criteria.

Practical implications – Implications can be derived both for business managers involved into the decision-making process and for suppliers identifying the most promising features of software quality.

Originality/value – The originality consists in the combination into a hybrid approach of the strong points of the AHP with the fuzzy set; the inclusion of multiple perspectives of decision criteria for service supplier selection, basically the "software product" and "supplier" ones; a real empirical application to test and demonstrate the efficacy and the practical utility of the proposed approach.

Keywords Multi-criteria decision making, Fuzzy logic, Analytic hierarchy process (AHP), Service supplier, Software supplier selection

Paper type Research paper

1. Introduction

Over the past years, the service economy is increasingly growing (Suh and Park, 2009) and even companies like the manufacturing firms that are out of the service industry have become more and more reliant on service-based businesses (Hidaka, 2006). In high technology firms, purchased materials and services represent up to 80 percent of the total product cost (Weber *et al.*, 1991). Manufacturers have strong technical- and product-oriented capabilities, but

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are often weak in service-oriented ones (Neu and Brown, 2005). Thus the purchasing department can play a key role in an organization's efficiency and effectiveness since it has a direct effect on cost reduction, profitability and flexibility; selecting the right service suppliers significantly reduces the purchasing costs and improves corporate competitiveness (Ghodsypour and O'Brien, 2001). Hence (Van der Rhee *et al.*, 2009), suppliers delivering such services are therefore critical for successfully providing solutions (Windahl and Lakemond, 2010; Johnson and Mena, 2008; Martinez *et al.*, 2010; Gebauer *et al.*, 2013) for two main reasons: at first, each supplier is involved in a long-term relationship with the buyer, providing continuous support and maintenance; second, the constantly growing demand for comprehensive maintenance services (Öhman *et al.*, 2015) implies long-term contracts with a relationship-based business logic (Brax, 2005; Oliva and Kallenberg, 2003). Of consequence, service supplier selection is an intrinsically complex multi-criteria decision-making (MCDM) problem (Chan *et al.*, 2008; Sadiq and Khan, 2006), involving simultaneously multiple requirements and fuzzy conditions. Among the others, the uncertainty and imprecise numeric values of decision data (including when information is sometimes incomplete and/or unknown condition) and the subjectiveness and imprecision of human behavior need to be taken into consideration (Kuo and Liang, 2011). Several MCDM methods exist for assisting decision-making with multiple objectives (Bruno *et al.*, 2012). There are no better or worse techniques, but simply some techniques better suited to particular decision problems than others do (Dağdeviren, 2008). Among the MCDM approaches explored in the literature, the analytic hierarchy process (AHP) (Saaty, 1980, 2000) is one of the most widely discussed methods both in supplier selection in general, often also in combination with other well-known techniques, such as the fuzzy set theory (FST) (Zadeh, 1965).

However, despite the widespread use of the mentioned methodologies for supplier selection, service supplier selection in manufacturing companies have received little research attention until recently (Bastl *et al.*, 2012). Nevertheless, while the number of applications is growing, there is little empirical evidence of the efficacy and practical usefulness of such tools (Weber *et al.*,1991; de Boer and van der Wegen, 2003) to handle service supplier selection in the manufacturing company. As a matter of fact, very often the AHP-based decision-making methodology proposed are tested on generic applications, numerical examples and computational experiments (Dahel, 2003; Saen, 2007; Ting and Cho, 2008; Ordoobadi, 2009). Less emphasis on the problems emerging in the practical implementation of the approach, on its strengths and weaknesses, and on the appreciation given to them by practitioners and managers involved in the decision-making processes (Bruno *et al.*, 2012, 2016) is provided in the literature. The result is a clear dichotomy between theory and business practice (Bruno *et al.*, 2012). In other words, the literature is rich in models which present a variety of approaches that are rarely used to solve real problems in the corporate practice (Genovese *et al.*, 2013, 2014).

In an attempt to cover the above dichotomy, the goal of this paper is to implement in a corporate environment a hybrid fuzzy extended analytic hierarchy process (FEAHP) approach for evaluating and selecting a particular category of service supplier: the software selection. The approach is based on two popular methodologies proposed in the literature to address evaluation problems, the AHP and the FST, proposing a hybrid approach combining the main strengths of both. On the basis of recent research (Esposito and Longobardo, 2011; Bruno *et al.*, 2015, 2016) on the application of AHP and FST approaches in real firm practices, the effectiveness and robustness of the two approaches considered separately can be summarized as follows: AHP appears to be relevantly suitable for determining the relevance weights associated with the selection of an evaluation criteria, meanwhile the FST model seems to fit significantly for alternative performance assessment in the place of rating scores derived from classical AHP approach.

The proposed hybrid approach, that leverages the benefits of the two methodology, is implemented and applied for supporting the selection of a Test Data Management System

(TDMS) within an aerospace manufacturing company. TDMS allows to effectively manage experimental data acquisition throughout the complete product design and development process. Choosing the appropriate TDMS requires a comprehensive supplier selection process from a finite number of alternatives which have to be evaluated and ranked considering simultaneously several criteria, concerning both the software system and the related service suppliers. Issues emerging during the implementation phase and subsequent results trigger some interesting implications regarding the model itself and its usability in the manufacturing industry. Implications can be derived both for company managers involved into the decision-making process of evaluation and for suppliers identifying the most promising features of TDMS for manufacturing companies.

The rest of the paper is organized as follows. Section 2 provides the literature background about the problem of service and software supplier selection. Section 3 proposes the fuzzy extension of AHP as a hybrid approach to afford the service supplier selection. After that, Section 4 presents the application of the model to the evaluation and selection of a TDMS software within an aerospace company. Finally, discussions of the main results are provided in Section 5. Conclusions and implications are reported in the last section to derive strategic insights to deal with practical applications of the methodology.

2. Background: service supplier selection

In an industrial context, a service is a process of doing something for another party by integrating internal and external capabilities in order to co-create value (Vargo and Lusch, 2008). A provider of infrastructure services (Hallikas *et al.*, 2014) needs to master both cost efficiency and service quality in order to outperform its rivals (Fließ and Kleinaltenkamp, 2004). Indeed, service supplier selection has a significant impact on the optimization of the quality, quantity, timeliness, and price of purchased goods and services (Dulmin and Mininno, 2003; Ghodsypour and O'brien, 2001; Sarkis *et al.*, 2007). Other authors classify the supplier attributes and their levels into four broad conceptual categories: cost, delivery performance, value-added service/support, and flexibility (Van der Rhee *et al.*, 2009).

According to Kahraman *et al.* (2003), the selection criteria typically fall into one of the four categories: supplier criteria, product performance criteria, service performance criteria and cost criteria. Service performance criteria can be used to evaluate the benefits provided by the supplier's services and they include: follow-up, technical support, lead time and professionalism (Kilincci and Onal, 2011). In the case of software services, the selection of software provider (SP) (Chin and Fu, 2014) depends on two areas of selection criteria, i.e., the enterprise and the SP ones, and the enterprise ones are closely related to the quality characteristics of the software product to be introduced in the company. It is evident that there is no common identification of factors guiding the supplier selection process in the literature (Chamodrakas *et al.*, 2010).

Given the importance of the supplier selection process, the identification of the appropriate evaluation and selection methodology is a quite delicate issue representing a very attractive research area. Numerous techniques have been described in the literature allowing for the selection of the best supplier according to different criteria: these techniques are more or less appropriate depending on the particular buying situation, generally developed through a ranking process of a set of suppliers previously qualified that are then judged based on an ensemble of relevant attributes and criteria. In dealing with software service supplier selection problems, the evaluation and selection methodology should integrate features and best practices of both the service selection context and the supplier selection one. While the academic literature is very comprehensive, the effective evaluation and selection of suppliers for service delivery continues to be challenging in many industries, especially in manufacturing.

In the context of software selection and evaluation, the AHP is one of the most widely discussed methods (Jadhav and Sonar, 2009, 2011; Lin *et al.*, 2007). AHP is a methodology suggested and developed by Thomas Saaty (1980, 2000) that aims at choosing from a number of alternatives based on the values and judgments of individuals called to decide how well these alternatives rate against a chosen set of intangible qualitative as well as tangible quantitative criteria. AHP applications include a variety of aspects: selection of a workflow management system (Kim and Moon, 1997), selection of a multimedia authoring system (Lai *et al.*, 1999), evaluation of AHP software (Ossadnik and Lange, 1999), evaluation and selection of an antivirus and content filtering software (Mamaghani 2002), evaluation and selection of e-commerce software and communication systems for supply chain (Sarkis and Talluri, 2004), selection of CRM (Colombo and Francalanci, 2004), evaluation of knowledge management tools (Ngai and Chan, 2005), and ERP system selection (Wei *et al.*, 2005; Parthasarathy, 2014).

The strength of the AHP approach is that it provides a structured and relatively simple solution to complex decision-making problems in the form of a multilevel hierarchic structure of integrated decision criteria that reflects the values, goals, objectives, and desires of the decision makers (Saaty and Vargas, 2001) with a large degree of flexibility (Bruno *et al.*, 2012). Nevertheless, despite its popularity and simplicity in concept, AHP-based selection approaches have been often criticized for their inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-maker's perception to precise numbers (Dağdeviren, 2008). To overcome these shortcomings and to efficiently handle difficult evaluation and selection problems, AHP can also be integrated with other well-known techniques, such as FST. FST, first introduced by Zadeh (1965), was specifically designed to mathematically represent uncertainty and vagueness, and resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It provides formalized tools (Zadeh, 1976) for dealing with the degree of imprecision and noise intrinsic to the variables considered in many real-world problems, allowing the decision makers to incorporate unquantifiable information, incomplete information, non-obtainable information, and partially ignorant facts into the decision model (Mohanty *et al.*, 2005). Hybrid AHP/FST models have been successfully employed in a wide range of studies concerning not only software selection problems (Bozdağ *et al.*, 2003; Shamsuzzaman *et al.*, 2003; Lin *et al.*, 2007; Chang *et al.*, 2008, 2009; Calabrese *et al.*, 2013; Ertay *et al.*, 2011; Zeydan *et al.*, 2011; Lee *et al.*, 2011) but also, in general, supplier selection ones (see e.g. Bruno *et al.*, 2009; Kang *et al.*, 2010; Kilincci and Onal, 2011), allowing not only to combine strengths of the two tools but also to overtake some of their weaknesses in both the just mentioned decision-making contexts.

The implementation and use of fuzzy-based extensions or modifications of AHP to solve many practical selection problems among alternatives has been successfully explored in a wide range of recent studies concerning both software selection problems and more general supplier selection ones. As regard the problem of software systems selection and evaluation, Bozdağ *et al.* (2003) compared four groups of decision-making methods, including a fuzzy AHP for selecting computer-integrated manufacturing systems. Shamsuzzaman *et al.* (2003) developed a computational framework that combines both fuzzy sets and analytical hierarchy process for selecting the best-ranked flexible manufacturing system. Lin *et al.* (2007) proposed a fuzzy MCDM procedure to facilitate data warehouse system selection. Chang *et al.* (2008) integrated fuzzy theory and hierarchy concepts to provide decision makers or buyers with a valuable guideline for evaluating software quality.

3. A hybrid approach for service selection

The hybrid approach based on the two most used methodologies in the literature, the AHP (Saaty, 1980, 2000) and the FST (Zadeh, 1965) will be now described in this section, starting from a brief theoretical overview of AHP and FST foundations and detailing hereinafter the proposed AHP fuzzy extension methodology.

3.1 *The AHP methodology*

The AHP methodology can be summarized into the following four steps:

- Step 1. Construction of hierarchical problem structure: the first step allows a complex decision problem to be structured into a hierarchy descending from an overall objective, reflecting the goal of the decision, to various "criteria," "subcriteria," and so on until the lowest level containing the selection choices, as represented in Figure 1.
- Step 2. Establishment of comparative judgments: through a standardized nine-point numerical scale of judgments introduced by Saaty (1980), this step assesses the relative influence of decision elements at each hierarchy level by making pairwise comparisons whose results can be summarized within an evaluation matrix.
- Step 3. Estimation and consistency measurement of local priorities: the term "local priorities" refers to both criteria weights and rating scores indicating preference among the alternatives. The classic AHP estimates the values of local priorities by normalizing the principal eigenvector α corresponding to the largest eigenvalue λ_{max} of the pairwise comparison matrix. The quality of the local priority vector so derived can be checked by calculating a consistency ratio (Dağdeviren, 2008), depending on λ_{max} and the order n of matrix, whose accepted upper limit is 0.1.
- Step 4. Synthesis of local priorities into global priorities: synthesizing the local priorities into global priorities means to obtain a total aggregate score for each alternative by combining the calculated weights of each decision criterion with rating scores of alternatives through a weighted sum of the type:

$$R(k) = \sum_{i=1}^{n} w_i \cdot r_i(k) \tag{1}$$

where $R(k)$ is the overall score of kth alternative; w_i is the importance weight of ith criterion; and $r_i(k)$ is the relative score of kth alternative with respect to ith criterion.

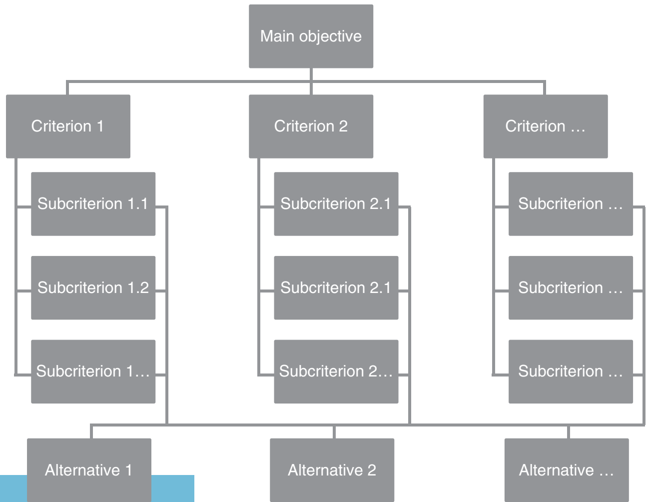

Figure 1.
Hierarchical structure of the AHP model

3.2 Fuzzy sets and fuzzy numbers

The concept of FST was introduced by Zadeh (1965) to deal with the vagueness of human cognitive processes and to represent vague, ambiguous, or not precisely and easily measurable information. FST implements sets of data with boundaries that are not sharply defined (i.e. fuzzy). A fuzzy set is a class of objects characterized by a membership or characteristic function, which assigns each object a continuous grade of membership to the set ranging between 0 and 1, and so expresses the degree of strength which a particular element belongs to a fuzzy set with. A fuzzy number is a special fuzzy set whose type is defined and identified by the typical geometric shape of its membership function that can be trapezoidal type for trapezoidal fuzzy numbers (TrFN) as shown in Figure 2, triangular type for triangular fuzzy numbers (TFN), or rectangular type for rectangular ones (RFN).

3.3 The hybrid fuzzy extended AHP approach

In the classical formulation of AHP, human's judgments concerning assessment of both importance of criteria and alternative performance are represented as exact numbers. The evaluation of relative importance of alternatives requires a high degree of complication and subjective judgments, due to the large number and variety of basic evaluation items that lies behind each subcriterion. In many practical cases, decision makers might be reluctant or unable to assign exact values to the comparison judgments of alternatives by making pairwise comparisons according to usual AHP methodology (Chan and Kumar, 2007). Instead, it feels more confident and simple to judge performance of alternatives by means of ranges of judgment based on fuzzy numbers, rather than through fixed judgments based on precise numbers, allowing to speed up the assessment process, to catch the nuances of decision makers' perceptions and to better emulate human preference model.

Hence, in order to efficiently handle the fuzziness of the information involved in deciding the most suitable TDMS and its supplier, an AHP model extension, based on FST and inspired by the research of Bruno *et al.* (2016), is presented and used in this work.

From the investigation conducted by these authors on the application of AHP and fuzzy extended AHP approaches in real firm practices, some methodological weakness and strengths have emerged. In particular they have found some distortions introduced by AHP and FST techniques in the perceptions and computation of performances and weights associated to criteria adopted in the selection process. When AHP is adopted for alternative performance evaluation, differences are not properly tracked and the final outcomes of the model appear significantly altered. Moreover, as regards the FST approach, when decision makers are inquired to state judgments about the weights associated with different criteria,

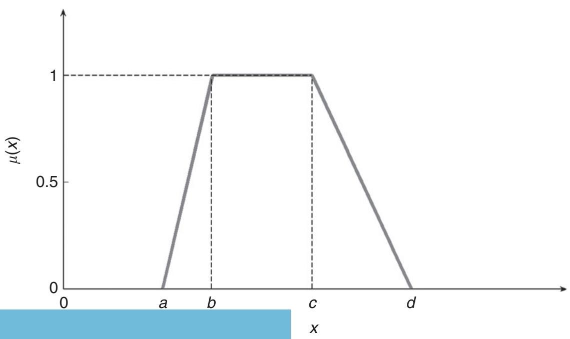

Figure 2.
Membership function of a trapezoidal fuzzy number (TrFN)

a kind of a flattening/overestimating effect of weights assessment is triggered. Therefore, with reference to the implementation of an AHP/FST hybrid supplier selection system, Esposito and Longobardo (2011) and Bruno *et al.* (2015) suggest that the AHP approach appears relevantly suitable for weights determination; meanwhile FST seems to fit significantly for performance estimations, as shown schematically in Figure 3.

Considering this evidence, in the proposed FEAHP, approach relevance weights associated with the criteria are determined by classical AHP, while judgments on TDMS/supplier performance are assigned through trapezoidal and TFN, corresponding in this paper to certain linguistic judgments directly assigned for performance evaluation in place of rating scores derived from usual pairwise comparison matrix. Weights and rating scores of alternatives so determined are then combined through a modified fuzzy version of Equation (1), returning a total aggregate fuzzy score for each alternative. Finally, in order to profile the final rank of alternatives and to identify the best one, the fuzzy score so resulting is "defuzzified," that is translated in a scalar number, thereby obtaining a synthetic rating index reflecting the overall judgment of decision makers on software system supplier performance. On the basis of its values, alternatives will be sorted from the best, identified by the biggest defuzzified final rating, to the worst, countersigned with the lowest defuzzified final rating.

In summary, the proposed FEAHP approach can be conceptualized according to the five steps depicted in Figure 4 and implemented in Section 4.

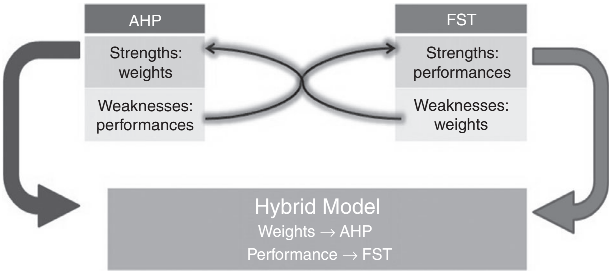

Figure 3.
Strengths and weaknesses of AHP, FST, and hybrid models

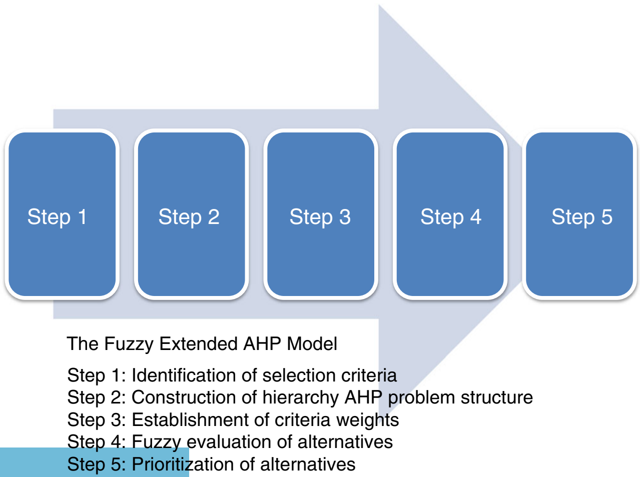

Figure 4.
Five stage-based fuzzy extended AHP model

4. The empirical case: the hybrid fuzzy extended AHP approach implementation

The objective of this section is to illustrate in detail how the proposed Fuzzy Extended AHP approach can be implemented in a manufacturing company to support the decision-making process for the supplier evaluation and selection of a new software whose importance impacts the competitiveness of the company: a TDMS.

4.1 The empirical context

The empirical context where the Hybrid FEAHP methodology is applied is a manufacturing enterprise with approximately 4,600 employees and revenues for more than €2 billion. The company is leader in the design, development, and production of components and systems for aerospace propulsion, working in the whole life cycle of the product – from design to maintenance, repair, and overhaul services – in the civil and military areas. The company needed to implement a new enterprise information technology (IT) system for test data management in order to create an official and long-term test data repository, facilitate analysis and retrieval of data, enable data and document collaboration between experimental centers and engineering departments and finally support the workflow of the entire testing process. Furthermore, the advanced TDMS that the company planned to develop would have to be able to be integrated in the context of new product development process and related IT management systems. According to aerospace development programs and international standards (AECMA STANDARD prEN 9130, 2000), the system should be able to ensure for test data storage a retention period of several years at least equal to the operational life of the product (an average of 25-30 years up to 50 years in some cases) for product data analysis and tracking. The volume of test data is estimated to be more than ten terabytes per year. So the establishment of a TDMS has been considered strategic for the chosen company.

The selection of the most suitable TDMS for the company has been assigned to a decision-makers' committee composed by three experts of IT department with IT and business background, including three managers operating in "Development of IT processes and projects for engineering and manufacturing," "IT Infrastructures for engineering," and "Purchasing and supply chain" offices. They had an average age of 7.5 years' experience on IT projects concerning knowledge and product data management, enterprise portals, and collaborative working environments. The knowledge of domain experts is important for understanding the uncertainties relevant for particular industry sectors and for capturing the appropriate 'system thinking' attitudes.

The decision-makers' committee has been supported by a researcher of an Italian University in the choice and practical implementation of the discussed evaluation and selection methodology. The application of the FEAHP approach has been developed in the company over a total period of two months, through the involvement for about three weeks of a certain number of representative users of different departments having at least a five years of experience in the company and a considerable expertise in their particular fields. The selected key users have been involved through three structured interviews, one individual and two collective, in order to identify the main users and functional requirements of TDMS.

In the next section, the proposed approach will be illustrated taking into consideration all the described steps.

4.2 Step 1: identification of selection criteria

In almost all reviewed literature articles concerning service software evaluation and selection the adopted software evaluation criteria are preferable to the software quality characteristics defined in the ISO/IEC 9126-1 standard of 2001 that specifically addresses quality model definition and its use as framework for software evaluation (ISO/IEC 9126-1, 2001). The ISO/IEC 9126-1 (2001) has been technically revised and replaced by ISO/IEC 25010 "System and software quality models" of 2011, which incorporates the same software quality characteristics with some amendments and additions. ISO/IEC 25010 (2011) defines software quality as "the degree to which a software product satisfies stated and implied needs when used under specified conditions" and categorizes system/software product quality properties into eight characteristics: functional suitability, reliability, performance efficiency, usability, security, compatibility, maintainability and portability (ISO/IEC 25010, 2011).

A drawback of the existing international standards is that they provide very general quality models and guidelines that are very difficult to apply to a specific domain (Yuen and Lau, 2011). Thus, we have used ISO/IEC 25010 (2011) quality model as a raw basis to construct, customize and refine our decision model for TDMS evaluation and selection. In particular, among the eight quality characteristics aforementioned, functional suitability, usability, maintainability, and portability have been identified as meaningful criteria for purposes of company during assessment meetings and field surveys conducted by a joint working group including a university's researcher and IT managers of the company. Of course, performance efficiency, security and compatibility criteria have not been ignored but have been used as a preliminary filtering checklist on top of the selection problem in order to identify the three shortlisted potential alternatives to be evaluated.

The first two criteria (functional suitability and usability) have been decomposed into more detailed subcriteria on the basis of functional requirements of TDMS and business needs and drivers of the company under discussion. In particular, functional features were refined during several meetings with key users of the company experimental centers and engineering departments having at least a five years of experience in the company and a considerable expertise in their particular fields to ensure that user requirements were all collected and well formulated. Tables I and II show the subcriteria of functional suitability and usability criteria, respectively.

To define the subcriteria concerning maintainability and portability summarized, respectively, in Tables III and IV, we have been partially inspired by the architectural quality decision variables investigated by Colombo and Francalanci (2004) for selection of CRM packages. However, compared to the literature, the strongest contribution of novelty

Criterion	Subcriteria
Functional suitability	Workflow management
	Data life cycle management
	Capturing context
	Test data management
	Analysis and graphics tools
	Customizable content organization
	Interoperability
	Data ETL (extraction-transformation-loading) functionalities

Table I.
Functional suitability subcriteria

Criterion	Subcriteria
Usability	Degree of personalizability
	Operability
	Learnability

Table II.
Usability subcriteria

we have made is the introduction of product support and system administration as subcriteria referring to maintainability, and the inclusion of licensing as subcriterion of portability.

In addition to the previous evaluation criteria we have also included in our decision model costs and supplier characteristics, as suggested in several studies of the literature reviewed. The criterion related to software costs has been added because of the obvious budget constraints of any IT project of software development. Suppliers characteristics criterion has been embraced because IT managers of the company consider TDMS suppliers to be not only simple software vendors but rather true business partners, able to understand the aerospace business processes, to contribute to their improvement and to develop the best possible IT system. For the particularized decomposition of both these criteria, we have adopted as a useful starting point the categorizations proposed by Jadhav and Sonar (2011) and Lin *et al.* (2007). Tables V and VI illustrate the subcriteria chosen for software costs and supplier characteristics, respectively.

Table AI describes the criteria and subcriteria for TDMS supplier selection to derive some insights into the strategic decision process.

4.3 Step 2: construction of hierarchy AHP problem structure

In this phase, we have structured the complex decision problem in question into a hierarchy descending from the overall objective to the various criteria, subcriteria and so on until the lowest level of alternatives. The overall goal of the decision is represented at the top level of

Criterion	Subcriteria
Maintainability	Modularity Scalability Product support System administration

Table III. Maintainability subcriteria

Criterion	Subcriteria
Portability	Standards compliance Licensing Installability

Table IV. Portability subcriteria

Criterion	Subcriteria
Costs	Direct costs Indirect costs

Table V. Costs subcriteria

Criterion	Subcriteria
Supplier characteristics	Profile Reputation Information on business product line Ongoing technical support\maintenance

Table VI. Supplier characteristics subcriteria the hierarchy. To achieve this goal, six strategic criteria, namely, functional suitability, usability, maintainability, portability, costs and supplier characteristics, have been arranged along the second level of the hierarchy. Then, the third level of the hierarchy reveals the 24 subcriteria defining the practical meaning of the six strategic criteria and used to compare the performance of alternatives. Finally, the TDMS/supplier alternatives are laid down at the last level of the hierarchy.

The hierarchical structure of the objectives has been constructed after three formal meetings within three weeks by a steering committee of three senior managers coming from the company IT department supported by a researcher of an Italian University. In particular, the committee included a manager with the responsibility to integrate the new system into the hardware and software infrastructure of the company, a manager with the responsibility to buy the new system, and the general manager of TDMS development project with the responsibility to formulate the project plan, integrate project resources, and implement a suitable TDMS solution.

The process of constructing the hierarchical structure was both analytic, starting from the main best practices and evaluation criteria employed in the literature and illustrated in ISO/IEC 25010 (2011) software quality standard, and dialectic, based on group discussions capturing the individual tacit knowledge of decision makers and the organization's stated common objectives structure (see Figure 5).

4.4 Step 3: establishment of criteria weights

Following the AHP methodology, the decision makers have made individual evaluations using the nine-point numerical scale introduced by Saaty (1980) to determine the criteria and subcriteria paired comparison matrices. Since the decision makers were striving for the same organization's stated objectives and have more in common than in conflict, consensus has been easily reached in merging individual judgments in a single group assessment and constructing a unique set of pairwise comparison matrices for all the evaluators.

Each of the pairwise comparison matrices obtained has been translated into the corresponding largest eigenvalue problem and the normalized priority weights for all criteria have been derived and summarized in Tables VII and VIII.

The consistency test results have proved to be all less than the threshold value of 0.1 for all comparison matrices revealing that the evaluators have been consistent throughout the pairwise comparison process.

4.5 Step 4: fuzzy evaluation of alternatives

As for the lowest level of the hierarchy containing the performance scores of alternatives, decision makers have not followed the usual AHP approach implying the assessment of pairwise comparisons among the alternatives for each subcriterion, but have assigned rating scores using a linguistic scale of judgment, composed by the terms very poor (VP), poor (P), medium (M), good (G) and very good (VG), each of which corresponding to a numerical interval of judgment rather than a precise numerical value and so parameterized by a fuzzy number.

For determining the membership functions associated with these linguistic terms, the technique suggested by Bruno *et al.* (2016) has been applied. At first, a set of rectangular fuzzy numbers – one set for each decision-maker – has been derived by asking the decision-makers' numerical ranges corresponding, respectively, to the term set VP, P, M, G, VG, as summarized in Table IX. Then, for each linguistic term, RFNs so collected have been combined together through set theory operators of intersection and union in order to obtain a set of membership functions associated with the considered term set VP, P, M, G, VG.

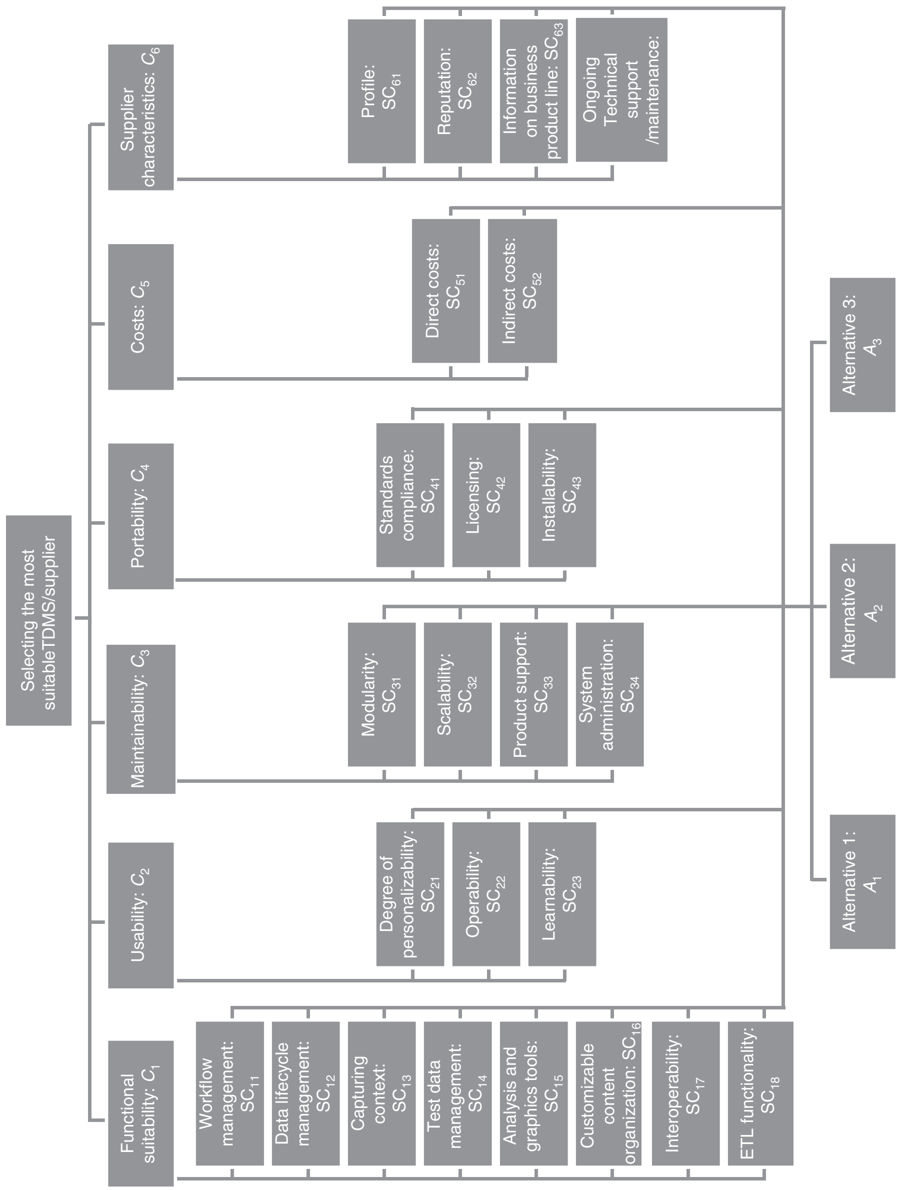

Figure 5.
Hierarchical structure of TDMS/supplier evaluation and selection problem

In particular, the range where the membership function assumes maximum value (equal to 1) is defined on the limits corresponding to the intersection or nearly intersection of the judgments collected from multiple decision makers; the border values (where the membership function is equal to 0), instead, are labeled on the extreme values of the range given by the union of collected judgments.

Table VII.
Local priorities (weights) for criteria of level 2

Criteria	Weights	Rank order of importance
C_1	$w_1 = 0.279$	1
C_2	$w_2 = 0.165$	2
C_3	$w_3 = 0.132$	3
C_4	$w_4 = 0.096$	5
C_5	$w_5 = 0.049$	4
C_6	$w_6 = 0.279$	1
	1.000	

Table VIII.
Local priorities (weights) for criteria of level 3

Subcriteria	Weights	Rank order of importance
SC_{11}	$w_{11} = 0.090$	7
SC_{12}	$w_{12} = 0.036$	8
SC_{13}	$w_{13} = 0.102$	4
SC_{14}	$w_{14} = 0.247$	1
SC_{15}	$w_{15} = 0.183$	2
SC_{16}	$w_{16} = 0.091$	6
SC_{17}	$w_{17} = 0.097$	5
SC_{18}	$w_{18} = 0.154$	3
	1.000	
SC_{21}	$w_{21} = 0.196$	3
SC_{22}	$w_{22} = 0.311$	2
SC_{23}	$w_{23} = 0.493$	1
	1.000	
SC_{31}	$w_{31} = 0.115$	3
SC_{32}	$w_{32} = 0.080$	4
SC_{33}	$w_{33} = 0.249$	2
SC_{34}	$w_{34} = 0.556$	1
	1.000	
SC_{41}	$w_{41} = 0.109$	3
SC_{42}	$w_{42} = 0.344$	2
SC_{43}	$w_{43} = 0.547$	1
	1.000	
SC_{51}	$w_{51} = 0.333$	2
SC_{52}	$w_{52} = 0.667$	1
	1.000	
SC_{61}	$w_{61} = 0.443$	1
SC_{62}	$w_{62} = 0.197$	3
SC_{63}	$w_{63} = 0.081$	4
SC_{64}	$w_{64} = 0.279$	2
	1.000	

Table IX.
Qualitative ranges associated by decision makers to the five linguistic terms

Decision makers	Linguistic terms VP	P	M	G	VG
D_1	[0;0.4]	[0.4;0.6]	[0.6;0.8]	[0.8;0.9]	[0.9;1.0]
D_2	[0;0.3]	[0.3;0.5]	[0.6;0.7]	[0.7;0.8]	[0.8;1.0]
D_3	[0;0.2]	[0.2;0.4]	[0.4;0.6]	[0.6;0.8]	[0.8;1.0]

The results of this process are summarized in Table X which shows that the membership functions practically obtained and used in this work are trapezoidal type for the extremes VP and VG and triangular type one for the others.

The linguistic judgments of suitability for the three alternatives given individually by decision makers under each subcriterion are listed in Table XI.

Many methods exist to combine fuzzy opinions of multiple decision makers such as mean, median, max, min and mixed operators (Buckley, 1984). Since the average operation is the most commonly used aggregation method, as indicated for instance in the following works (Chen, 2001; Cochran and Chen, 2005; Lin *et al.*, 2007), the fuzzy mean operator has been used to aggregate the fuzzy judgments of decision makers about TDMS alternatives.

Once transferred on a spreadsheet all the criteria local priorities and average fuzzy ratings of TDMS/supplier alternatives, the global priority of each alternative has been calculated through a fuzzy weighted sum by combining AHP-based priority weights with fuzzy rating scores. The results are represented graphically in Figure 6 and presented in Table XII.

Table X. Fuzzy numbers representing final linguistic variables derived from a combination of decision makers' judgments

Linguistic terms	Fuzzy numbers *a*	*b*	*c*	*d*	Membership function type
VP	0.0	0.0	0.2	0.4	Trapezoidal
P	0.2	0.4	0.4	0.6	Triangular
M	0.4	0.6	0.6	0.8	Triangular
G	0.6	0.8	0.8	0.9	Triangular
VG	0.8	0.9	1.0	1.0	Trapezoidal

Table XI. Linguistic assessment results for alternatives under each subcriterion

	Alternatives								
	A_1			A_2			A_3		
	Decision makers								
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Subcriteria	Linguistic judgments			Linguistic judgments			Linguistic judgments		
SC_{11}	G	G	G	M	M	M	M	G	M
SC_{12}	G	G	M	M	M	P	M	G	G
SC_{13}	VG	M	G	VG	G	G	VG	G	G
SC_{14}	VG	G	VG	M	M	P	VG	VG	VG
SC_{15}	M	G	M	M	M	P	VG	VG	VG
SC_{16}	M	M	G	M	G	M	M	M	G
SC_{17}	M	G	G	M	G	M	G	M	M
SC_{18}	G	G	M	M	M	G	G	VG	G
SC_{21}	M	G	M	P	G	P	G	G	M
SC_{22}	G	M	G	M	M	M	VG	G	G
SC_{23}	G	G	G	M	M	P	G	G	G
SC_{31}	G	VG	G	G	G	VG	VG	G	G
SC_{32}	G	G	M	VG	M	G	G	G	G
SC_{33}	VG	G	G	M	M	M	VG	VG	VG
SC_{34}	VG	G	VG	M	G	M	VG	VG	G
SC_{41}	M	G	G	M	G	M	M	M	M
SC_{42}	G	G	G	VG	VG	VG	VG	VG	G
SC_{43}	M	G	G	VG	VG	G	VG	G	G
SC_{51}	M	M	M	VG	G	G	G	G	G
SC_{52}	VG	G	VG	VG	VG	VG	M	M	M
SC_{61}	VG	VG	VG	G	M	M	VG	VG	VG
SC_{62}	M	M	M	G	G	G	VG	VG	G
SC_{63}	G	VG	VG	G	M	M	VG	G	G
SC_{64}	G	M	M	M	M	M	G	G	G

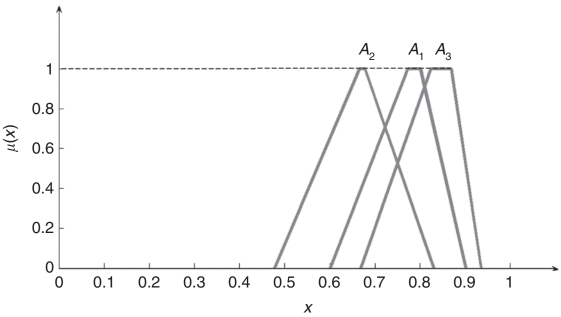

Figure 6.
Fuzzy aggregate scores of alternatives

Table XII.
Fuzzy aggregate scores and ranking values of alternatives

Alternatives	Fuzzy aggregate score	Final defuzzified aggregate score
A_1	(0.601, 0.773, 0.801, 0.901)	0.769
A_2	(0.478, 0.666, 0.678, 0.830)	0.663
A_3	(0.669, 0.824, 0.869, 0.935)	0.824

4.6 Step 5: prioritization of alternatives

In order to profile the final rank of the alternatives and identify the best one, alternatives have been sorted from the best, identified by the biggest defuzzified final rating, to the worst, countersigned with the lowest defuzzified final rating. The final fuzzy rating resulting for each alternative has been "defuzzified," that is translated in a scalar number, by using the center of area method (Bortolan and Degani, 1985; Zimmermann, 2001) because of its low computational complexity and high diffusion of practical use. The final defuzzified aggregate scores so obtained and summarized in Table XII show that A_3, having the highest score compared to the others, has proved the top performing TDMS/supplier, with A_1 and A_2 following in second and third positions, respectively. Thus, the committee of decision makers certainly recommended alternative A_3 as the best TDMS/supplier to satisfy the objectives of the company. However, it is worth noting that the first two obtained scores by the suppliers are very close, reporting a slight relative score difference ((0.824-0.769)/0.824 = 6.67 percent). And so, in addition to A_3, the committee invited also vendor A_1 to implement a proof of concept (PoC) of the proposed TDMS and to demonstrate it on-site within the company, in order to field test by means of a software product prototype – as suggested in ISO/IEC 25040 (2011) – the needed features and requirements and any customizations of the proposed software product. In fact, it should be noted that the subsequent phase of empirical evaluation of top TDMS PoCs installed within the IT environment of the company may also modify the overall final judgment in favor of an alternative placed second, as well as the results of contracts negotiation in the final phases of purchase.

5. Discussions

Fuzzy judgments adopted to assess the alternatives have allowed decision makers to have three main advantages: to practically and quickly judge the alternatives against the considered subcriteria; to catch the nuances of individual sensations and judgments; and to incorporate into the decision model not exactly quantifiable, incomplete, non-obtainable or partially obtainable information that are inevitably present in any real-world decision problem. These three advantages are reflected in the easiness to use the proposed service evaluation approach that proves to be very simple from a computational standpoint, being ultimately based on a weighted average of ratings. In addition, the adoption of traditional

AHP methodology for assessing the relevance weights of decision criteria has made possible to take into account fully, precisely, and in a structured way, the actual priorities and stated objectives of the company, revealing the exact requirements of the software system that the company really wants to buy. The decision criteria used in this paper integrate many different aspects of a complex service selection problem (software quality features, costs, supplier characteristics, etc.) and, apart from the functional subcriteria which are of course strongly focused on the discussed empirical case, they allow to get the right mixed level of abstraction and concretization for the requirements of a generic service selection problem, so contributing to enhance the body of knowledge of the decision support system.

In fact, as they have both been derived from a software quality model based on ISO/IEC standards and included also costs and supplier characteristic evaluations, the adopted criteria can represent the foundations of a generalized service selection process which can be used as best practice to select any software service in any business sector (not only in the manufacturing or aerospace ones).

Moreover, even if the calculated weights of the selected evaluation criteria and subcriteria should incorporate the own stated priorities of the discussed company, they could be assumed from other business companies as a practical reference guide of numerical values in order to set their own ones, or simply refine them. Accordingly a short discussion about the used weights will be now provided.

5.1 Priority weights of selection criteria

The estimated priority weights summarized in Table VII show that the functional suitability and supplier characteristics (reputation) have been ranked at the first place among the high-level decision criteria, followed by usability, maintainability, costs, and portability. This indicates that software technical features and supplier characteristics play a more significant role among the strategic evaluative objectives of the company. It is also important to observe that costs appear as a criterion with a lower priority than others because the initial economic proposal of top TDMS suppliers may undergo significant changes during the final phase of contract negotiation. However, information about software system costs cannot be totally neglected at this stage because of the obvious limitations of project budget.

5.2 Priority weights of selection subcriteria

Referring to the subcriteria weights illustrated in Table VIII, "test data management," "analysis and graphics tools," and "ETL data functionalities" represent in respective order the most important evaluation factors for company's purposes among subcriteria related to technical features.

Concerning usability criterion, the subcriteria identifying "usability," "learnability," and "operability" exhibit weights of importance greater than that of "degree of personalizability," showing that the easiness with which users can learn the overall system functionalities and operate on them is valued more than the possibility to personalize the software modules or the layout of graphical user interface.

From a system maintainability point of view, "system administration" and "product support" are judged in a more meaningful way if compared to the remaining two subcriteria, considered the degree of importance that the company attaches more to ensuring a proper functioning of the system, rather than to the modularity and scalability features of the system.

As regards the portability criterion, "installability" and "licensing" appear as evaluative subcriteria of greater relevance compared to "standard compliance," taking into account the impacts that these two aspects can determine on IT infrastructural and architectural features of the company.

As far as the priority of costs subcriteria, the indirect costs have been identified with the highest priority compared with the direct ones, as highlighted by the relative valued weights in Table VIII, since, unlike the direct ones – that are initial fixed costs – they represent recurring costs over the years for the company related to maintenance and system upgrading activities.

Finally, "supplier profile" and "ongoing technical support/maintenance," immediately followed by "reputation," appear as evaluative elements of greater strategic importance for the company among the subcriteria defining the features of the most suitable TDMS supplier.

6. Conclusions and implications

The service software supplier selection for complex manufacturing industries represents a quite delicate issue for IT managers and a very attractive area of interest for researchers. Quite often, methodologies dealing with the suppliers selection process are just tested on numerical exemplification, with little attention to the problems that arise during the practical implementation and during the practical usefulness of such formalized tools in practice (Bruno *et al.*, 2012). In this paper an easy to use and systematic hybrid FEAHP approach has been presented and applied to support the decision-making process of the IT managers of an Italian aerospace company in the selection of one of the most relevant service categories for a manufacturing company: the software supplier satisfying the business context requirements. The described empirical case study has allowed to appreciate the practical usability and applicability of this research work within a real corporate environment in order to contribute to bridge the gap between theoretical approaches and empirical applications.

The contribution of this research can be identified in the inclusion within the same decision-making approach multiple perspectives, basically the "software product" and "supplier" ones, due to the integration of AHP and FST (two methodologies used for dealing with the software and supplier selection problem, respectively) and the combination of the evaluation criteria related to both the software product and the supplier.

The implementation has been carried out by analyzing, in a detailed manner, each step of the implementation of the hybrid approach, highlighting the benefits and shortcomings related to its use. The illustrative case has shown that the integrated methodology can be adopted as a strategic tool to manage complex software service selection problems, providing advantages to the company in terms of clearness in mapping the decision-making process and transparency of the evaluation process.

6.1 Theoretical implications

Compared with models from Yeh and Chang (2009) the hybrid approach has a lower level of computational complexity, which facilitates its practical application. Differently from what is illustrated in the literature, the hybrid model proposed and assessed in this paper combines the procedure for deriving criteria weights typical of the AHP approach with performances drawn from an FST approach. In this way, the computational complexity of the fuzzy-AHP application is reduced, and the practical application is facilitated. While FST and AHP are well-established methodologies, their application in the way proposed in this paper represents another contribution, as, to the best of our knowledge, has not been proposed in similar studies for service selection. In the proposed model, the criteria for software supplier selection have been clearly identified and the problem structured systematically after a scrupulous comparative analysis among ISO/IEC guidelines, literature about software, service and supplier selection problems, and business drivers of the company.

Starting from this extensive analysis, the novelty introduced in this paper is that the problem of selecting a business software application has been approached from two points of view – different but integrated – the first one related to the selection of a "software product" and the second one referred to the selection of a "supplier." So, the first level of evaluation criteria has not only incorporated very specific requirements of the software product, such as the quality ones, but also integrated extensively features related to the product and the supplier. With regard to the product ones, new subcriteria referring to maintainability, such as product support and system administration, and a new one concerning the portability, such as licensing, have been also introduced. Finally, this paper sets out also to identify, apply, and present the most suitable decision-making method that can be used to solve simultaneously both the two aspects of a software service selection problem.

6.2 Managerial implications

Managerial implications can be drawn both for the company using the methodology and for the suppliers involved in the processes.

As regards the company, from one side the adoption of traditional AHP technique for structuring the decision-making model has made possible to share experiences and information between decision makers allowing to transform their individual tacit knowledge into collective explicit knowledge directed toward organizational objectives and productivity. The set of calculated relevance criteria weights has been unique for all decision makers, given the need to embody the organization's stated common objectives and priorities. From the other side, the use of linguistic terms of judgment parameterized by trapezoidal and TFN has allowed to greatly speed and facilitate the assessment process of alternatives, which was not really easy due to the large number of basic evaluation items related to the considered subcriteria. The alternatives performance ratings have been assigned through Fuzzy-based linguistic judgments individually by each decision-maker, and then aggregated in order to catch their subjective perceptions and preferences. The presented FEAHP model has proved therefore to be able to significantly reduce the time and effort of managers in the decision-making process, also because it does not involve cumbersome mathematical operations and can be simply transferred to a spreadsheet for easy computations and to automatically obtain the ranking order of alternatives. Moreover, the top management of company's IT department judged favorably the decision model mechanism developed in this paper, considering it very useful, practical and advantageous for future IT benchmarking activities. Although the discussed application is related to a specific software system, the selected high-level evaluation criteria have covered entirely the software service requirements of the company in a such a satisfactory way that they could be used to select both other services or the next software products of the company. IT top managers have also proposed to make potential suppliers aware and informed about the adopted evaluation system and decision criteria weights during the future software selection process of the company.

Indeed, looking at the managerial implications for the suppliers, the adopted decision framework and evaluation tree can represent a useful tool to identify their strengths and weaknesses, to adopt the appropriate operational strategies and implement the right corrective actions in order to improve their own performances, their products, and the degree of satisfaction of their customers. At this purpose the enhancement of the ongoing support/ maintenance is a critical aspect to be monitored and to be enhanced. Moreover, the developed methodological approach has appeared to IT managers of the company so powerful and versatile that they have suggested to promote its adoption to other multi-criteria strategic decision problems within different areas and departments of the company. Indeed, the application proposed contains both "general" criteria to be used for other service supplier selection (such as the "supplier characteristics – reputation, ongoing support and maintenance," "usability") as well as service-specific criteria identifiable in "functional suitability" and "usability." This allows to easily appreciate the level of generalization of the approach to the selection of service software supplier. Moreover, the approach can be used in big company as a strategic tool supporting the decision making along the whole supply chain.

IT managers strongly believe that the discussed method is flexible enough to be effectively applied within other complex manufacturing industries such as automotive, railways, and shipbuilding. As a matter of fact, the power of fuzzy extended AHP methods has been validated by empirical applications in a great diversity of real industrial problems requiring a selection between alternatives (Celik *et al.*, 2009; Onüt *et al.*, 2009; Abdi, 2009; Cebeci, 2009; Esposito and Longobardo, 2011), also thanks to the high flexibility of the hierarchical tree decision structure that, depending on the degree of complexity of the decision problem to be analyzed, can be simply changed. However, compared with the reviewed literature, this paper has contributed to make IT managers more aware about the issues emerging on a real and complex problem in the practical implementation of such formalized decision-making tools, and to help them to overcome these challenges by providing a new, easy to use, and methodological approach for supporting decision making in service supplier selection, from two integrated contexts, the "software product" and the "supplier" selection ones, combined in both the selected evaluation criteria and the adopted hybrid model.

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Further reading

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Appendix

Criterion	Subcriteria	Definition
Functional suitability criteria		
Functional suitability	Workflow management	Availability to model and track the workflow in order to link steps of test process to aerospace product development workflow Ability to support reviews and approval of testing activities performed
	Data life cycle management	Ability to trace the evolution of test data and contents, by documenting the history of approvals, reviews, testing configurations, execution, and the approved use of results
	Capturing context	Ability to manage metadata that affect the nature and purpose of tests the type, P/N and S/N of tested products the team member involved in testing activities other information concerning any motivations, decision criteria, recommendations or lesson learned
	Test data management	Ability for users to quickly insert, store, search, and access physical test content (i.e. data, results, logbook, daily reports, details about testing configurations, procedures, and nature of measurements) Availability of advanced query functionalities, mechanisms of data history, wizard to create, modify and import data and documents
	Analysis and graphics tools	Availability of software interfaces and specialized modules for end users to analyze, process, and plot data stored in the system about vibration tests, shock test, acoustic test, thermal tests, and tests concerning maintenance and overhaul activities performed on aerospace engine, components, and rotating parts
	Customizable content organization	Ability for users to reuse any test content (such as data, graphs, photographs, results, reports) and organize that content into standard templates, presentations, and customized views
	Interoperability	Capability of the system to integrate or be integrated into such software with complementary capabilities including PLM/PDM systems, simulation data management systems, commercial and in-house custom simulation packages, math tools
	ETL functionality	Ability of the system to collect data with different formats (ascii, cdf, cdf ascii, csv, ubr, uff58ascii, uff58bin, txt, xls) coming from different data acquisition systems Availability of suitable ETL tools or to be integrated in the system for helping the automatic processes of data extraction, transformation, and load
Usability criteria		
Usability	Degree of personalizability	Number of customized software package versions available to meet specific industry requirements Possibility to customize the layout of user interface reports produced by the system Possibility to personalize the software modules, expand their functionalities or create new ones by means of: high-level programming languages proprietary programming languages integrated development environments

(*continued*)

Table AI. Criteria for Test Data Management System (TDMS) supplier selection

Criterion	Subcriteria	Definition
	Operability	Easiness with which user can operate on the application, including: user friendliness of system interface step by step guided operations (wizards) multi-language support
	Learnability	Easiness with which user can learn the overall system functionalities, including the availability of guidebooks, user manuals, online help on-site training web-based resources such as forum, mailing list, wiki, community knowledge base
Maintainability criteria		
Maintainability	Modularity	Number of independently installable modules of software system Ability to distribute modules on different servers
	Scalability	Ability to support an increasing number of users Ability to support higher loads of transaction
	Product support	Typology of technical support channels available Availability of methodologies, best practices or of a technical staff supporting software release upgrades Existence of a planned roadmap for the next stable software releases Management priority of identified issues and maximum time of issue resolution Warranty terms, conditions and limitations
	System administration	Ability to set up roles and user profiles Ability to manage and controlling security by setting individual and group access rights Availability of directory services (active directory, LDAP) to perform the previous configuration tasks Ability to enable the authentication to the system through a password that is user-modifiable Possibility to monitor and check software system operations (through tracking, logging and audit trail tools) Availability of reports with statistics on user accesses Availability of utilities for application configuration, data backup and restore, monitoring and tuning system performance, and for reports generation and other administrative operations
Portability criteria		
Portability	Standards compliance	Breadth of compliance of software system with: middleware standards (ODBC, JDBC, OLE_DB) DBMS standards (MS-Access, MS-SQL, MS-Excel, Oracle, DB2, Informix, Sybase, MySQL, Ingrace, PostgreSQL) communication standards (EDI, XML)
	Licensing	Software license type (free, commercial named-user or floating licenses or mixed, and modular) Number and type of licenses required for customization or software development activities
	Installability	Compatibility with the operating systems (both for client and server) Maximum number of clients simultaneously supported Type of installation (distributed or centralized) Ability of the application to run on virtual infrastructures Ability to split the software system into separate application tiers that can be distributed on different servers

Table AI.

(*continued*)

Criterion	Subcriteria	Definition
Costs criteria		
Costs	Direct costs	Licensing fee Hardware cost External consulting fee to install and implement the system
	Indirect costs	Maintenance costs System upgrading costs Training costs
Supplier characteristics criteria		
Supplier characteristics	Profile	Size (number of employees) Scale (level of internationalization) Economic performance Financial status Quality certification Quality of demo and discussions held on-site
	Reputation	Trust for the supplier according to: global market share number and quality of references (especially in aerospace domain) length of in-depth experience about software systems development number of installations of software system
	Information on business product line	Turnover of the product Investments in R&D Number of employees involved in design, R&D and technical support activities
	Ongoing technical support/ maintenance	The candidate supplier partner should ensure: short delivery lead time long-term and on-site technical assistance low response time high quality of service support ease of communication release of tutorials, user manuals, troubleshooting guides and training courses

Table AI.

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