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A hybrid Fuzzy-Promethee method for Logistic Service selection

Design of a decision support tool

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Abstract— ***This paper presents a hybrid multi-criteria/fuzzy method for the selection of the carrier among a number of pre-selected logistic service providers.***

The method was developed and applied to the case of a multinational company in the Power-electronic market. Finally, an automated system supporting the decisional process was designed to support users.

Keywords-Carrier selection; multi-criteria/fuzzy; decisional process; support system.

I. Introduction

The outsourcing of logistics activities to third-party logistics service providers has now become a common practice for a number of strategic and operative reasons [1]. According to the Langley et al. 3PL survey [2], inbound/outbound transportation is among the most common outsourced activities of logistics. Transportation is in fact one of the most important logistic activities having a significant impact on both customer service and costs [3].

In this sense, the adequate selection of the most effective and efficient transport mode and relative carrier become operatively an essential part of the logistic decisional process.

The aim of this work is to design a decision supporting tool in order to enable decision makers to understand the problem and to support the evaluation and selection of carriers by a systematic methodology which can combine quantitative and qualitative data. The real case of a multinational company in the Power-electronic market is also presented.

II. Problem Statement

The transport service selection is a complex process because objectives are often conflicting, full information is not available, multiple objective/subjective criteria and different persons are usually involved, a large number of alternatives exists, etc.

The importance and number of the selected factors obviously varies with the company, the shipping scenario and the aim of the evaluation. Usually, in order to create a vendor list (pre-selection phase), the number of considered criteria is higher than in the final choice of the carrier.

The selection process is complex and time consuming since services are often not directly comparable and there are many subjective criteria (such as reputation, satisfaction), which are difficult to define. Hence to standardize and automate the decisional process, to codify the experience of experts, and to structure qualitative information can lead to significant benefits for companies.

The research objective is to define an effective method for the carriers selection and design a decision supporting tool. In this aim, the process has to be structured and standardized in order to be executed in a simple and cost-effective way. Relevant information for the selection process has to be identified and effective decisional methods should be defined in order to create a final ranking among the suitable alternatives.

To examine these aspects according to the case of the multinational company we design a decision supporting tool which could assist users in the carrier choice.

III. The Adopted Model

Our problem can be framed into a Multiple Criteria Decision Making context, characterized by a set of finite alternatives and attributes (measures of performance of the alternatives according to some evaluative criteria).

In figure 1, a logical scheme of the adopted decision model is presented. To obtain evaluation measures a pre-processing on raw data is performed.

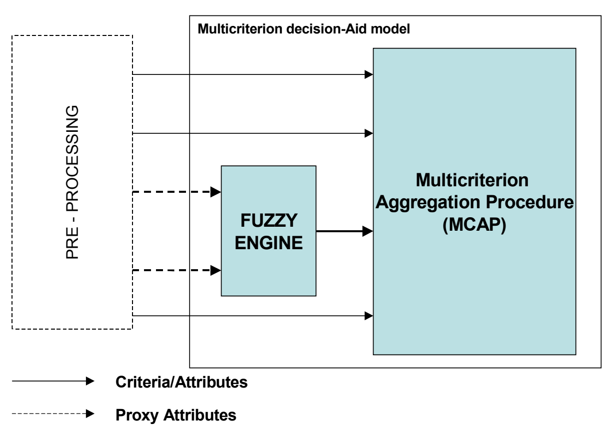

Figure 1. The evaluation model – a logical framework.

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A fuzzy inferential approach is chosen to manage the problem of synthesizing different “proxy attributes” (e.g. linguistic variables vs numerical indicators, objective performance indexes vs subjective judgments) strictly related to a same evaluative criterion, according to a non linear and experience – based reasoning. The next stage is a Multicriterion Aggregation Procedure (MCAP) consistent with the decision making context; the output is a final ranking of the alternatives.

In the two following sections we describe some basic issues related to the techniques used to implement the above presented model.

IV. THE MULTICRITERION AGGREGATION PROCEDURE

Multicriteria Decision-Aid Methods (MCDA) can be interpreted as a four steps process (figure 2), that we enforced in the following way:

i) *structuring the Decision Making Situation (problem)*: we have a finite set of alternatives, a family of quali/quantitative evaluation criteria (attributes), an evaluation matrix containing quali/quantitative values. Attributes have different optimization directions (maximizing and minimizing);

ii) *modeling the preference:* the preference structure uses discrimination thresholds (quasi-criteria, see Brans and Mareschal [4]) accordingly to the decision-maker’s value system;

iii) *aggregating the preferences*: as our desired output is a total or partial ranking of the alternatives (considering their possible incomparability), we had to choose the most suitable Multi Criteria Aggregation Procedure starting from literature guidelines [5] [6] [7].

We chose the outranking method “PROMETHEE II”, integrated with the GAIA (Geometrical Analysis for Interactive Assistance) procedure because PROMETHEE:

- can simultaneously deal with qualitative and quantitative criteria. Criteria scores can be expressed in their own units;
- takes into account *equivocality* (the extent to which information is unclear and suggests multiple and conflicting interpretations [8]; it is related to data reliability, missing values, stochastic nature of events, human subjectivity), manage qualitative criteria enabling a very flexible elicitation of preferences, and manage non compensatory decision logic;
- referring to other outranking methods (ELECTRE) introduces more functions (six) to describe decision-making preferences for each criterion (flexibility) with a clearer interpretation of the parameters (threshold values have a clear meaning in terms of the alternatives);
- gives the possibility to eliminate *scaling effects* (i.e. different economic significance of the differences in the performance measures to consider the *amplitude of the deviation* [4] managing a partially compensatory effect, to manage incomparability;
- with respect to other widely used techniques (AHP), PROMETHEE does not aggregate good scores on some criteria and bad scores on other criteria, as in AHP, has less pair-wise comparisons and it does not have the artificial limitation of the use of the nine-point scale for evaluation as in AHP.

PROMETHEE II, in particular, provides a complete ranking of alternatives from the best to the worst one. In our case, it is more useful to present a ranking of options than a

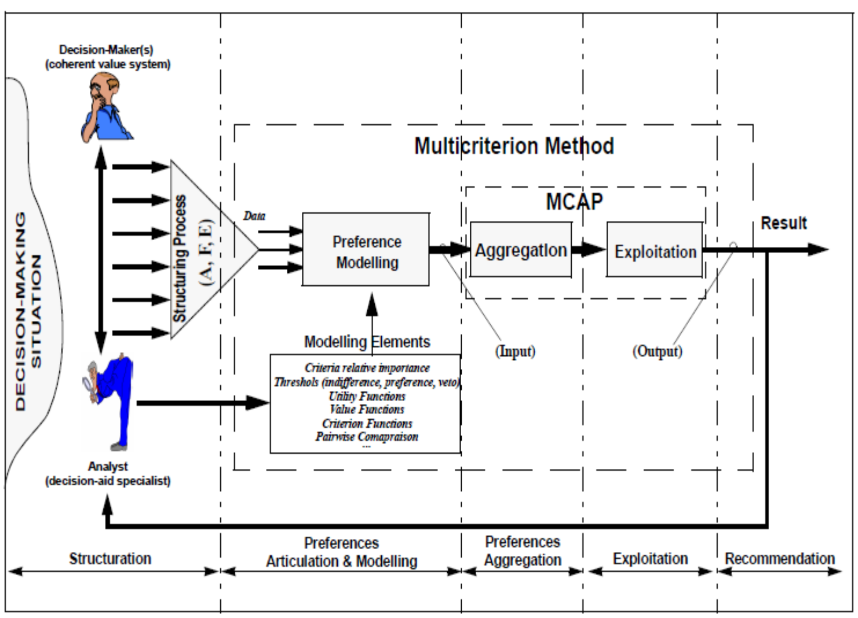

Figure 2. Multicriterion decision-aid process (source: Guitoni et.al. [5])

single solution. In this sense, it is useful to supply to the decision maker information on how the final ranking changes when different decisions on weights, criteria and aggregation procedures are taken [9].

Finally, we chose the PROMETHEE because of its easiness, its efficiency and its interactivity as it has a transparent influence of each criterion and weight on the solution. Another main advantage is that the evaluation is based on the importance of a performance difference between two solutions.

In addition to this, an user-friendly software (Decision Lab, 2000) is available for performing the calculations even though the level of complexity of this algorithm is low.

iv) *exploiting the aggregation procedure and formulation of recommendations.*

V. THE FUZZY INFERENCE

In the MDCA context, Fuzzy set Theory may be applied with different purposes in the following main phases [10]:

1. Rating – Aggregation of judgments with respect to all goals and decision alternatives
2. Ranking – Definition of the rank ordering of the decision alternatives

Fuzzy models can help in fact MCDA at different level:

- Rating assessment
- Weight assessment
- Alternative Ranking

When Fuzzy set Theory is used in expert systems or Decision Support Systems (DSS) it is often because they use linguistic variables and approximate reasoning.

In this work a hybrid fuzzy-promethee methodology was applied to synthesize a final ranking of available carriers. The fuzzy logic and PROMETHEE are used in sequential way to deal respectively with the Rating assessment of particular input variables and the Alternative Ranking. Sometimes, in fact, some input data (proxy attributes) cannot be defined within a reasonable degree of accuracy, and a stochastic approach (treat the imprecision as a probability) is not applicable. Furthermore, the aggregation model to obtain the measure of specific evaluation criteria is not linear and strongly connected to single judgments and experience. For those reasons we chose to combine Fuzzy set Theory and MCDA analysis.

VI. CASE STUDY

The case study application is about a multinational company running in the Electronic Power Systems and Alternative Energy Systems Market (the identity will remain hidden for privacy reasons). It is one of the world's leading manufacturers of power-conversion equipment for the telecommunications, networking, and technology markets.

The company experienced an impressive increase in last decade which is the result of core business growth and of the penetration of new markets, including the entry into new applications, facilitated by acquisitions. This caused a progressive increase of the logistic costs, so that, currently, one of the most critical targets for the company is to reduce them. It was clear, for the company, the need to simplify and automate the decisional process in order to better control the logistic costs and to improve the process efficiency. For this reason we started the design of a decision support tool providing users with relevant information about the carrier choice.

Up to date, when a new and not programmed shipping occurs (as for example MRO materials, unconformity, urgent or special shipping, etc.), the carrier selection is up to the Logistic Manager who, on the basis of his experience, choose the best provider among a number of preselected partners, taking into account both context factors and evaluation criteria such as: shipping type (included Incoterm), source/destination, shipping importance (maximum allowed lead time), costs (depending on dimensions, weight, chargeable weight, tariffs or pricing policy), delivery performance (time and quality), reliability of carriers (potential damaged or lost shipping), etc.

Owing to his many years' experience, the logistic manager usually knows when to use each carriers according to the shipping scenario (priority, customer criticality, etc.), to obtain a better performance-rate ratio. This process, even if sometimes effective, is not codified, difficult to generalize and to decentralize and very time consuming as well.

A. System Design

In the case study we refer to a specific (standard) scenario in which no particular conditions of urgency or shipment occurs, so that the weight of the criteria can assign priority to the price dimension However, the same scheme, for exception of the weight of criteria, is valid also in the other scenarios.

A team of experts from the company logistic function and university was built for the project. The following steps were accomplished:

TABLE I. DESCRIPTION OF THE EVALUATION CRITERIA.

ID		Criteria	Description	Data type
C_1		*Freight Costs*	Service costs	regular
C_2		*Transit Time*	Declared time for the shipping	regular
C_3	C_{31}	*Delivery Time (Time reliability)*	Number of shipping respecting the stated time	Performance index
	C_{32}	*Quality reliability (Service Quality)*	Number of unconformity (damaged, lost shipping or other custom problems.)	Performance index
	C_{33}	*Forwarder response*	Capability to quickly respond to a single request	Subjective judgment

1. *Identification of factors affecting the carrier choice.*
As the table 1 shows, three criteria were selected to compare suppliers (Costs, Time and Reliability). Two of them (C1 and C2) belong to regular data derived from the contract agreement, the other one (C3) is more subjective and depends on three main sub-dimensions (C31, C32 and C33, we called "Proxy Attributes"). To date, these are subjective variables standing to the judgment and experience of the logistic managers since historical data are not fully available. The company is also working to structure two more objective performance indicators as concerning the Time and Quality Reliability.

2. *Definition of the Fuzzy assessment logic.*
The Fuzzy set Theory is used to pre-process variables C31, C32, C33 in order to finally evaluate an overall Reliability index according to the Logistic manager experience. Initially, inputs are provided form the logistic managers for each carrier alternative, then C31 and C32 will be periodically updated according to the collected data, while C33 will be modified according to judgments based on a Likert evaluation scale by the Logistic Manager.

Three fuzzy variables (three triangular linguistic variables Low-Middle-High were used for each input) and an output variable (with five triangular) was created in collaboration with the company expertise. Then the analysts discussed and specified their screening heuristics, so that this expertise or knowledge could be translated into proper fuzzy IF-THEN rules. 27 rules were defined.
An overall Reliability indicator is finally synthesized by the de-fuzzification of the output variable. Carries alternatives which do not respond to the fixed acceptance threshold are excluded from the process.

3. *Definition of the Promethee assessment logic.*
The standard PROMETHEE-GAIA methodology was followed [11]. The input to the Promethee process are C1 and C2, (which are generated from a specific pre-processing routine according to the shipping data provided by the users) and C3 (a Reliability index is available for each pre-qualified supplier). The PROMETHEE preference functions were defined in collaboration with the Logistics team.
4. *Design of the decision tool.*
The tool architecture is showed in figure 3. The users

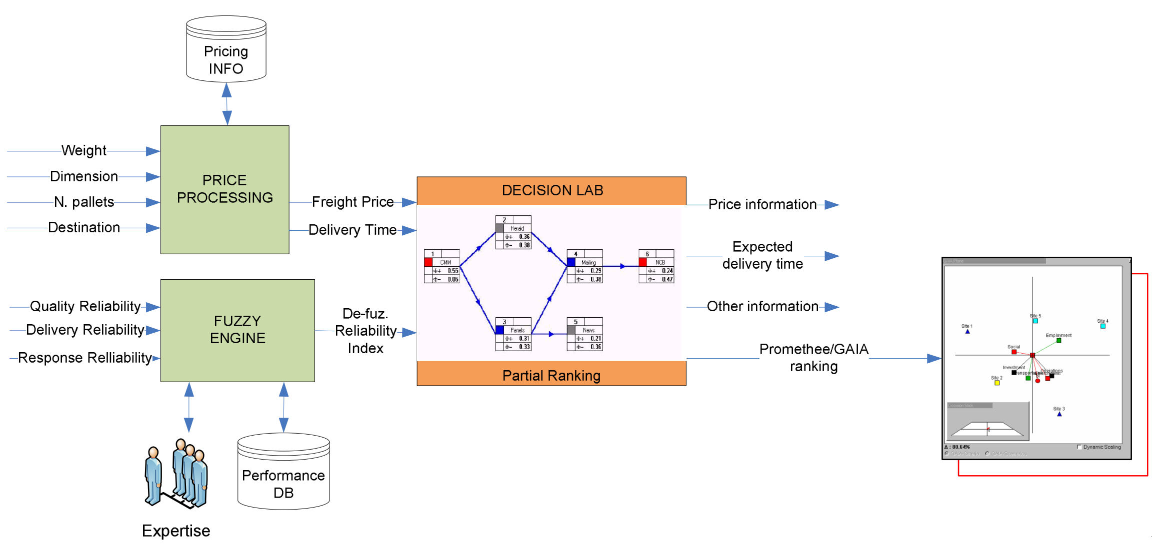

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Figure 3. Tool architecture

provide the system with the shipping details. Data used to elaborate C1 and C2. C3 is periodically updated starting from the carrier's performance and the manager evaluations.

Hence, inputs are available to Decision Lab 2000 which will give back to the user: a final ranking of the alternatives, information about time, tariffs and reliability, a graphic comparison of the alternatives on the GAIA plane, the possibility to perform sensitivity analysis (robustness of the solution according to weight's variations).

The GAIA analysis could be particularly appreciated at a tactical-managerial level since the information related to the decision problem can be represented in a k-dimensional space (alternatives are represented by points and criteria by axes). The GAIA plane is obtained by projection of this information on a plane so that as few information as possible get lost. The conflicting criteria appear clearly: criteria expressing similar preferences on the data are oriented in the same direction; conflicting criteria are pointing in opposite directions. The projection of the weights vector in the GAIA plane corresponds to another axis (π, the PROMETHEE decision axis) that shows the direction of the compromise resulting from the weights allocated to the criteria. Therefore the decision-maker can easily identify the alternatives located in the π direction [11].

5. *Realization and validation of a prototype.*
Till this stage of the work a prototype of the decision support tool has been developed. It is still not completely automated but it has allowed to validate the standard scenario.

VII. Conclusion and Expected Results

The major value of this paper is the development of a comprehensive methodology and an operative supporting tool which integrate different issues for the selection of a carrier.

Unfortunately, the work is still in progress, so that just few of the expected results are evidenced by the prototypical application. However a number of significant expected advantages can be listed.

The tool can in fact:

- Provide managers with a better understanding of the decision situation.
- Structure, standardize and codify the decisional selection process.
- Integrate different decision making perspectives by a flexible combination of fuzzy set theory and multicriteria methodology.
- Allow multi-scenario, what-if and sensitivity analysis.
- Allow graphic representation and comparison of the alternatives. The information relative to a decision problem including *k* criteria can be represented in a *k*-dimensional space. The GAIA plane is obtained by projection of this information on a plane such that as few information as possible get lost.
- Allow knowledge sharing to inexpert users and decisional decentralization.

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