Using the TODIM-FSE method as a decision-making support methodology for oil spill response

Aderson Campos Passos a,*, Marcello Goulart Teixeira b, Katia Cristina Garcia c, Anelise Menezes Cardoso c, Luiz Flavio Autran Monteiro Gomes d

a Department of Computer Engineering, Military Institute of Engineering (IME), Praça General Tibúrcio, 80, Praia Vermelha, Rio de Janeiro, CEP 22290-270, RJ, Brazil
b Department of Computer Science, Federal University of Rio de Janeiro (UFRJ), Caisa Postal 68.530, Rio de Janeiro, CEP 21941-590, RJ, Brazil
c Interdisciplinary Environmental Laboratory (LMA), Energetic Planning Program, (COPPE), Federal University of Rio Janeiro, Centro de Tecnologia Bloco I 2000 sala 208, Cidade Universitária, Rio de Janeiro, CEP 21949-900, RJ, Brazil
d Ibmec/RJ, Av. Presidente Wilson, 118, 11th floor, Rio de Janeiro, CEP 20030-020, RJ, Brazil

ARTICLE INFO

Keywords:
Multiple criteria analysis
TODIM-FSE
Oil spill response
SISNOLEO
Environmental damage

ABSTRACT

This paper introduces a multi-criteria method for solving classification problems, called TODIM-FSE. This name was chosen because its structure merges characteristics from two different methods: TODIM and FSE. In order to demonstrate TODIM-FSE, a model was constructed aimed at helping potential users to decide upon suitable contingency plans for oil spill situations. The model is envisaged as embedded within SISNOLEO (a Portuguese acronym for An Information System for Oil Spill Planning) which is subsequently described in the article. The fundamentals of this method, several key references and a case study are also provided.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Fuzzy Synthetic Evaluation (henceforth FSE) was first launched as an environmental index to evaluate the water quality in reservoirs [1]. In the same article, both the need to take into account several conflicting elements simultaneously, as well as the inaccurate judgments of these elements, were clearly underlined. This is why concepts of multi-criteria decision analysis, together with fuzzy logic were brought in.

Several papers have been published using the same methodology. Most of these have adjusted environmental modeling in order to create alternative evaluation indices [1,2,3]. However, articles using the FSE in well-defined decision problems [4,5] may also be found. For this reason, we consider FSE as a multi-criteria decision method.

Another multi-criteria method already known in the scientific literature is TODIM [6,7,8,9,10]. Its main feature is to take into account the risk embedded in the decision makers’ judgments, by adapting in its aggregation function the value function of Kahneman and Tversky’s Prospect Theory [11]. However, different from FSE, TODIM is a method that analyzes a set of alternatives (or courses of action) and provides their order of preference.

The main objective of the present text is to introduce an innovative method for solving multi-criteria classification problems (Pi) that merges characteristics from both methods (TODIM and FSE), and also demonstrate its characteristics, as well as describe the procedures aimed at obtaining final results. In order to illustrate these proposals for using this method (henceforth TODIM-FSE), a model is provided which has been applied in a case study. The aim had been to establish the most suitable contingency plan for each oil spill occurrence. A further research objective is to describe the context in which the model is applied. This is, namely, the development of SISNOLEO (an acronym in Portuguese for an Information System for Oil Spill Planning and Response). This paper will also provide a general description of the aforementioned system, in which the model was seen to be embedded.

Being able to act quickly in emergency situations, whether brought on by nature or not, is a clear concern and the literature abounds with proposed solutions. In this sense, [12] proposes an expert system for fast disaster assessment integrating fuzzy logic, Delphi method and several MCDM methods, while [13] develops a procedure to simplify the consistency test used in Analytical Network Process (ANP). As a result, it is possible to improve the efficiency of response decision making in risk assessment. In [14], a new expert system for disaster diagnosis is described and, in [15], a model was built in order to establish a rapid risk assessment applied to the tourism industry. Analyzing earthquake disasters as typical giant
complex systems, [16] presents the meta-synthesis assessment framework of these systems. In order to analyze earthquake situations, [17] presents an intelligent simulation system based on a development platform of a geographic information system and artificial intelligence. This previous paper intends to identify the weaknesses of the structure and infrastructure system in pre-earthquake conditions, quickly assess earthquake damages and respond in a fast and intelligent way to the public and the government. Meanwhile, [18] proposes a model to evaluate the relative severity of earthquakes in different regions of China.

In oil spill situations, several concerns must be taken into account simultaneously. One of them is the fate of the oil in a marine environment, as studied in [19,20]. The shoreline ecosystems sensitivity should also be considered in case of oil spill, as suggested by [21]. The model proposed in this article considers these last two aspects.

2. The TODIM-FSE method: A Pβ approach

The TODIM-FSE method assembles characteristics from two different multi-criteria methods. The fundamental idea of the FSE aggregation procedure is to derive a weighted sum of the membership values for each category. These weights relate to the relative importance of criteria. This should be carried out successively until a final vector is obtained. The components of this vector are the membership values for each alternative related to the defined categories.

To illustrate the general algebra for FSE, the hierarchical structure of the case study (Fig. 5) will be used as an example. This case will be described in detail in Section 3. The SC1, SC2 and SC3 sub-categories are subordinated to C1 criteria. The judgments for each sub-criterion will be transformed into the following vectors:

\[ V_{SC1} = [\mu_{small}, \mu_{medium}, \mu_{great}] \]
\[ V_{SC2} = [\mu_{high}, \mu_{medium}, \mu_{low}] \]
\[ V_{SC3} = [\mu_{short}, \mu_{medium}, \mu_{long}] \]

For this group of sub-criteria a vector of weights was established

\[ W_1 = [W_{SC1}, W_{SC2}, W_{SC3}] \]

In order to group these values, vector BC1 must be obtained, resulting from the following matrix operation:

\[ BC1 = W_1 \times AC_1 \]

where AC1 is a matrix obtained after the merging of the vectors V_SC1, V_SC2, V_SC3. Hence,

\[ BC1 = [W_{SC1}, W_{SC2}, W_{SC3}] \times \begin{bmatrix} \mu_{small} & \mu_{medium} & \mu_{great} \\ \mu_{high} & \mu_{medium} & \mu_{low} \\ \mu_{short} & \mu_{medium} & \mu_{long} \end{bmatrix} \]

\[ BC1 = [\mu_{national}, \mu_{regional}, \mu_{local}] \]

This procedure should be carried out for each criterion, and the final aggregation ought to occur as described below

\[ mu_{national} \mu_{regional} \mu_{local} \]

Final vector = \[ [W_{C1}, W_{C2}, W_{C3}, W_{C4}, W_{C5}] \times \begin{bmatrix} \mu_{national} & \mu_{regional} & \mu_{local} \\ \mu_{national} & \mu_{regional} & \mu_{local} \\ \mu_{national} & \mu_{regional} & \mu_{local} \\ \mu_{national} & \mu_{regional} & \mu_{local} \\ \mu_{national} & \mu_{regional} & \mu_{local} \end{bmatrix} \]

\[ Final vector = [\mu_{national} \mu_{regional} \mu_{local}] \]

To obtain the final classification, the choice of a category with a higher \( \mu \) value will be needed.

The second method, the TODIM (an acronym in Portuguese for Interactive and Multi-criteria Decision Making) is a multi-criteria method that has as its main feature the use of the paradigm of Prospect Theory by Kahneman and Tversky [11]. One of the characteristics of the Prospect Theory, whose authors were awarded the Nobel Prize in Economics for this work in 2002, is the analysis of human behavior in the face of risk. The method uses such characteristic adapting its aggregation function to incorporate this aspect of human behavior. Thus, the TODIM becomes an appropriate method to tackle problems with risk decisions. As a result, it provides the ordering of alternatives and therefore is characterized as a Pβ method.

The proposed method uses the initial stages of the FSE and the final stages of TODIM, adjusting it so that it is possible to obtain a result that represents the sorting of alternatives. Goodwin and Wright [22] suggested a set of steps to facilitate the understanding and application of SMART, a multi-criteria method proposed by Edwards [23]. A similar idea is used to define the decision making process by applying the TODIM-FSE. The following sections will describe each of the steps used for this method:

Step 1 – Definition of decision makers and decision analysts.
Step 2 – Detailed analysis of the decision problem and problem structuring.
Step 3 – Definition of the relevant criteria for the problem.
Step 4 – Definition of categories and contribution functions.
Step 5 – Establishment of the relative importance of the selected criteria.
Step 6 – Classification of each alternative in one of the proposed categories defined in step 4.
Step 7 – Validation analysis.

2.1. Definition of decision makers and decision analysts (step 1)

The decision makers are the people who will make judgments about the decision problem. The decision analysts are the specialists in decision support processes and methods. It may also be considered the possibility of aggregating judgments from experts in specific knowledge related to the problem. In this case, these experts will be regarded as decision makers.

2.2. Decision problem analysis and structuring (step 2)

The decision problem must be analyzed to verify the possibility and necessity of using a multi-criteria decision support method. Sometimes the problem is simple and does not require its use. If the decision problem is a classification of alternatives, then the TODIM-FSE method can be used. The relevance of problem structuring is widely recognized. A comprehensive set of references about the subject can be found in [24].

2.3. Definition of the relevant criteria for the problem (step 3)

This step involves defining what should be taken into consideration to make the decision. One way of defining these criteria is through a brainstorming session with people interested in the problem. After defining a large set of possible criteria it is necessary to select some of them. A set of criteria will need to be defined in order to match the qualities of completeness, nonredundancy, operationality, minimum size and decomposability proposed by Keeney and Raiffa [25].

2.4. Definition of categories and contribution functions (step 4)

In this methodological step, the decision makers’ preferences are used to define both the categories themselves and the...
boundaries between each of the categories. In this case, the first feature to be focused upon is the number \( k \) of categories to be classified. After defining the number of categories, the contributions that each criterion provides to classify an alternative within a certain category must also be defined. Contribution values should continuously vary between 0 (zero) and 1 (one), with value 1 (one) indicating that the criterion has a maximum contribution to classify an alternative within a given category.

Thus, we will let \( A \) be the set of criteria used to classify the alternatives; \( n \) will be defined as the cardinality of \( A \), and \( c \) as a generic criterion of \( A \).

The features of \( c \) will be evaluated by a specialist who, together with a decision analyst, will create contribution functions expressing their knowledge of the problem. Thus, suppose that crit \( i \) can be classified with \( k = 3 \). Using, as an example, the \( SC_2 \) sub-criterion from the case study (i.e., the type of oil in terms of its persistence – \( °API \)), three categories were defined, namely, local level (LL), regional level (RL), national level (NL). The model details will be explained later in the present paper. Fig. 1 illustrates a composition of sigmoidal functions, constructed using information given by specialists from the field of petroleum studies.

To define the level of contingency action for oil spill response, a hypothetical value of 21 \( °API \) for \( SC_2 \) will be used. Subsequently, a vector of \( k \) elements will be defined which denote the contributions associated for this value in each category. The resulting vector is:

\[
[\mu_{NL}(x) = 0.19 \quad \mu_{RL}(x) = 0.78 \quad \mu_{LL}(x) = 0]
\]

This approach may be used for both quantitative (similar to \( SC_2 \)), and qualitative criteria. The sub-criteria Environmental Sensitivity (\( SC_2 \)) in this case study, was evaluated using a cardinal scale with values ranging between 0 (zero) and 10 (ten). Another possibility for this modeling is to evaluate the alternative using a verbal scale associating each verbal judgment to a vector of contributions. In this case, when the evaluation is low, the resulting vector becomes:

\[
[\mu_{LL}(x) = 1 \quad \mu_{RL}(x) = 0 \quad \mu_{NL}(x) = 0]
\]

If the decision evaluation is a judgment between low and medium, for example, the resulting vector is:

\[
[\mu_{LL}(x) = 0.5 \quad \mu_{RL}(x) = 0.5 \quad \mu_{NL}(x) = 0]
\]

In addition, intermediate judgments may assume infinite combinations. However, there is a well-known human restriction in issuing qualitative judgments, described in Miller’s [26] classical article. For this reason, no more than 9 (nine) different levels in the verbal scale (associated with an equal number of vectors) are expected, in the evaluation of each qualitative criterion.

2.5. Definition of the relative importance between criteria (step 5)

In a seminal paper on FSE [1], the pairwise comparison matrices from Saaty’s Analytic Hierarchy Process (AHP) are the reference for defining the relative weights between criteria. His fundamental scale [27] has also been used to complete these matrices, as demonstrated in Table 1.

However, a variation of this procedure has been introduced in the present research, by which the inconsistency related to each pairwise comparison matrices may be eliminated. This is the same as that adopted in the TODIM method [6,7,8,9,10].

Inconsistency elimination will be accomplished utilizing the following steps:

a. Deriving the priority vector \( p \) from the pairwise comparison matrix, as proposed by Saaty [27], where

\[
p = [a_1, a_2, \ldots, a_n]
\]

b. From the weights obtained (as components of the priority vector \( p \)), an alternative matrix is built, as shown in (1). This matrix has a consistency index equal to zero, because its elements are determined by the ratio between the weights of criteria associated with that element. Therefore, if \( b_{ij} \) is an element of this matrix, then its value will be \( a_i/a_j \), where \( a_i \) and \( a_j \) are, respectively, the weights of criteria \( i \) and \( j \), as seen below

\[
\begin{bmatrix}
\frac{a_1}{a_1} & \frac{a_1}{a_2} & \cdots & \frac{a_1}{a_n} \\
\frac{a_2}{a_1} & \frac{a_2}{a_2} & \cdots & \frac{a_2}{a_n} \\
\vdots & \vdots & \ddots & \vdots \\
\frac{a_n}{a_1} & \frac{a_n}{a_2} & \cdots & \frac{a_n}{a_n}
\end{bmatrix}
\]

(1)

c. This newly generated matrix will be used in the modeling process. Each element of the priority vector \( W \) will be calculated as the direct row sum average. Subsequently, these values are normalized by dividing the elements by the sum of its components. This procedure, which was proposed by Saaty [27], replaces the calculation of the eigenvector of the matrix of paired comparisons. This is done to avoid the problems mentioned by
Bana e Costa and Vansnick [28] in the calculation of the eigenvector. Hence,

\[ W = (w_1 \quad w_2 \quad \ldots \quad w_n) \text{ where } \sum_{i=1}^{n} w_i = 1 \]

### 2.6. Classification of each alternative in one of the proposed categories (step 6)

To perform the classification of each alternative the aggregation function proposed in the TODIM method is used. As already mentioned, it takes into account the risk in decision making by incorporating the value function of Prospect Theory. The original result from TODIM method is the ranking of alternatives.

The inputs of TODIM method are the relative weights of criteria and the judgments assigned to each alternative from the perspective of each criterion. In the method presented in this paper the TODIM original aggregation function receives as alternatives, the \( k \) categories defined in step 4. The table of criteria grouped contributions, Table 2, contains contribution values of each criterion.

The Table 2 will store the values obtained in step 4. With these values the matrices of partial dominance \( (\Phi_{c}(\text{cat}_i, \text{cat}_j)) \) are constructed, one for each criterion \( c \). With these matrices the final matrix of dominance \( \delta(\text{cat}_i, \text{cat}_j) \), subject of the following equation, will be calculated.

\[ \delta(\text{cat}_i, \text{cat}_j) = \sum_{c=1}^{n} \Phi_{c}(\text{cat}_i, \text{cat}_j) \quad \forall(i,j) \]

with

\[ \Phi_{c}(\text{cat}_i, \text{cat}_j) = \begin{cases} \sqrt{\frac{w_{r} (\mu_{r}-\mu_{c})}{\sum_{c=1}^{n} w_{c} \mu_{c}}} & \text{if } \mu_{r} - \mu_{c} > 0 \\ 0 & \text{if } \mu_{r} - \mu_{c} = 0 \\ -\frac{1}{\sqrt{\frac{\sum_{c=1}^{n} w_{c} \mu_{c}}{w_{r}}}} & \text{if } \mu_{r} - \mu_{c} < 0 \end{cases} \]

The value \( w_{rc} \) represents the weight of criterion \( c \) divided by the weight of the reference criterion \( r \). The latter is the criterion that will hold the greater weight.

The value \( \theta \) is the attenuation factor of the losses. Different choices of \( \theta \) lead to different shapes of the prospect value function in the negative quadrant (Fig. 2).

The final classification of the alternative will be obtained with the analysis of the vector \( X \) (pronounced as “x”). Each of the \( k \) components of this vector represents the final contribution value that the alternative has in each category. The component with the highest value indicates the category selected for the classification. Each component \( \xi_i \) is calculated using the following equation:

\[ \xi_i = \frac{\sum_{j=1}^{k} \delta(\text{cat}_i, \text{cat}_j) - \min \sum_{j=1}^{k} \delta(\text{cat}_i, \text{cat}_j)}{\max \sum_{j=1}^{k} \delta(\text{cat}_i, \text{cat}_j) - \min \sum_{j=1}^{k} \delta(\text{cat}_i, \text{cat}_j)} \]

### 2.7. Validation analysis (step 7)

This is an important step in the model construction. Here, judgments with doubtful values may be repeated, in order to verify whether the variation affects the overall classification. This is followed by interviews with specialists, who are responsible for the definition of the contribution functions, as well as the weighting for criteria and sub-criteria. The coherence between the real problem and the classification obtained in the model may then be verified. If this is not achieved then a further analysis of the model will be necessary. In this way it may be possible to establish new weights for both the criteria and the new contribution functions.

### 3. Application context: The Brazilian oil spill information system (SISNOLEO)

The Brazilian contingency structure of response for oil spill is still under development. The Brazilian National Contingency Plan, for example, is being evaluated by national authorities and it is still awaiting government approval in a legal procedure which began in 2002.

A positive element in terms of the draft of the Brazilian National Contingency Plan is the SISNOLEO. This has been defined as an information system with real time access capable of collecting, analyzing, providing and disseminating all relevant information used in an efficient response action. As the draft of the Brazilian Plan fails to include details of the structure of the system, Cardoso et al. [29], Cardoso [30] and SISNOLEO/COPPE/UFRJ [31] proposed structural details, based on the international experience of Australia, Canada, USA and United Kingdom, as well as on the specific characteristics of Brazilian oil and gas exploration and production (E&P) activities.

According to their proposal, the system should be able to permit real time access and response to any oil spill accident reported in Brazilian waters, by identifying their geographic location and by the characteristics of the sites in question. To achieve this, the system has been devised in two different modules. The first focuses on the information needed to plan the different response levels to oil spills; the second focuses on the response actions themselves, as shown in Fig. 3. Thus, the system should be capable of collecting and disseminating all relevant information needed to guarantee an efficient accident response. This will include information regarding airports, railroads, ports, civil defense, hospitals, and other important data, such as that relating to hydrographic basins, satellite images, meteorological and oceanographic data, cartographic data and data on protected sites. All this data will be housed within a geo-referenced base, in order to achieve subsequent mapping elaboration, superposition and analyses.

It may be observed that certain parties may participate not only in the response module but also in the planning module. This underlines the fact that information acquired in past response actions may be used to define new planning strategies, a characteristic of continuous improvement and retro-feeding processes.

This paper proposes that a decision support methodology in the Response Actions Module of SISNOLEO, specifically in the

---

Please cite this article as: Passos AC, et al. Using the TODIM-FSE method as a decision-making support methodology for oil spill response. Computers and Operations Research (2013), http://dx.doi.org/10.1016/j.cor.2013.04.010
“Decision supporting tool” group of information, be included, using a model structured on TODIM-FSE. This tool aims to aid the decision-making regarding the evaluation of the accident, which will involve both the evaluation of the severity of the oil spill, as well as the selection of the appropriate level of response (Fig. 4). It is important to remember that this is an auxiliary tool which takes into account the most relevant criteria to be considered at the moment of an accident, according to the opinion and experience of an expert group of the environmental, risk analysis, contingency response and legal areas, both of government and private sector, consulted to aid the development of the proposed decision-tool. Nowadays, in Brazil, the final decision is made by a Sectorial Coordinator, who may also take into consideration further factors which have not been included in the tool, but which may be important in certain specific contexts.

3.1. Decision-support model for oil spill response and case study

The steps proposed in Section 2 were followed, in order to develop the decision-support model for oil spill response using the TODIM-FSE, as well as to establish the contribution functions of the input criterion for the system itself.

The model is designed to receive few input data and provide a quick decision support. Considering the Brazilian context, several criteria were selected. According to the location where oil spill occurs, the classification will be different.

Step 1: It was believed essential to enlist the participation of a group made up of experts in risk and accident analyses, in the oil sector and environmental fields. In this way the inclusion of relevant data and perceptions of key stakeholders usually involved in spill responses, would well be guaranteed.

Step 2: The problem was approached by experts with the decision analyst. The decision problem was identified as a classification of alternatives problem. The TODIM-FSE method was used.

Step 3: By carrying out the series of steps described above, it was possible to obtain six well-defined groups of criteria to aid an analysis. These are demonstrated in Table 3. The criteria were grouped according to their similarities and levels of interaction.

Step 4: The objective of this decision problem is to frame a contingency action for each of the following response levels categories, and to help agents to take positive decisions when oil spills occur:

- **Local level**: Demands the trigger of an Individual Emergency Plan (IEP), usually associated with small scale oil spills, generally near to the operator facilities and caused by failures in the activities of the installations. The IEP is a formal document which registers a set of response procedures in case an accident occurs on its installations.
Table 3 Criteria and sub-criteria of the decision problem.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Severity of accident</td>
<td>SC1: Volume spilled (l)</td>
</tr>
<tr>
<td></td>
<td>SC2: Type of oil in terms of its persistence (°API)</td>
</tr>
<tr>
<td></td>
<td>SC3: Spill duration (h)</td>
</tr>
<tr>
<td>C2: Chance of oil of reaching the coast</td>
<td>SC4: Distance from the spill to the coast (km)</td>
</tr>
<tr>
<td></td>
<td>SC5: Shift and spread of the spill (yes/no)</td>
</tr>
<tr>
<td>C3: Environmental sensitivity of the affected area</td>
<td>SC6: Environmental sensitivity (grade)</td>
</tr>
<tr>
<td>C4: Socioeconomic sensitivity</td>
<td>SC7: Presence of extreme sensitive ecosystems (yes/no)</td>
</tr>
<tr>
<td>C5: Response capacity</td>
<td>SC8: Tourism activities (grade)</td>
</tr>
<tr>
<td></td>
<td>SC9: Fishing activities (grade)</td>
</tr>
<tr>
<td>C6: History of previous spills in the affected area</td>
<td>SC10: Adequacy of the response equipment to the spill (grade)</td>
</tr>
<tr>
<td></td>
<td>SC11: Adequacy of the response team to the spill (grade)</td>
</tr>
<tr>
<td></td>
<td>SC12: Previous exposure to accidents as oil spills (grade)</td>
</tr>
<tr>
<td></td>
<td>SC13: Level of environmental degradation of the area (grade)</td>
</tr>
</tbody>
</table>

Fig. 5 provides a chart of the proposed model, highlighting the sources of information in the SISNOLEO response module. The final step defines contribution functions related to input criteria. Sigmoidal functions were chosen, and expressed by

\[ f(x) = \frac{1}{1 + e^{-ax + b}} \]

where \( a \) and \( b \) are chosen to best fit the curve to the information provided by the experts. A series of curves are represented in Fig. 6 for the criterion \( SC_1, SC_2, SC_3, SC_6, SC_8, SC_{10}, SC_{11}, SC_{12}, \) and \( SC_{13} \). The names outside the parenthesis represent the membership functions that were used by the FSE, in the example in the beginning of section 2. The names in parenthesis indicate the contribution functions in the TODIM-FSE.

In addition, the criteria \( SC_5 \) and \( SC_7 \) possess certain particularities. The sub-criterion \( SC_5 \) is considered a qualitative sub-criterion. Thus, when the shift and spread of the spill are considered favorable, the contribution values are \([1,0,0]\). Otherwise, where this proves unfavorable, the contribution values are \([0,0,1]\). The same logic is also applied to the sub-criteria \( SC_7 \).

Step 5: To define the relative importance between the criteria we used the procedures suggested in Section 2. The experts were interviewed and provided the following weights for the sub-criteria and criteria presented in Tables 4 and 5, respectively.

Step 6: Accident with an FPSO – Floating, Production, Storage, and Offloading Platform (Macaé, Rio de Janeiro State, Brazil)

Up to the previous step the generic decision model that provides the classification for any oil spill was defined. In this step, a specific oil spill will be subject to classification. This will be the article case study. An accident with an FPSO, 80 km out at sea from the city of Macaé, in the north of Rio de Janeiro State, caused a temporarily reduction of 2% in Brazilian oil production for the year 2002. The risk of a platform-sink was very high, as well as the risk of spilling the 12 million liters of stored oil on the vessel itself. The coastal region of this part of the Rio de Janeiro State contains several sensitive natural environments, including coastal lakes, river mouths, mangroves, sandy beaches, rocky slopes, colonies of sea birds, isolated environments beyond the reach of fishing and tourism. The input data is shown in Table 7. These data are taken to the contribution functions defined in Fig. 6 and provide the results shown in Tables 7 and 8. They represent the table of criteria grouped contributions for each of the sub-criteria (lower hierarchical level) and the criteria (higher hierarchical level), respectively.

The final result is the classification shown in Table 8(b). When defining the contribution functions it is necessary to identify how they contribute to the alternative classification. Experts will be important for this definition. For \( SC_2 \) sub-criterion (type of oil), for
example, the lower the API, the easier to remove it from the water, and therefore, the higher the contribution of such oil spills to the local level sorting. In contrast, for a sub-criterion as SC10 (adequacy of response equipment), the most appropriate are the equipment for oil removal, the greater the contribution to the oil spill to classify as local level. The Table 7 shows how each of the criteria contributes to the final classification.

Step 7: The validation analysis for this problem should take into account that this model must provide fast decision support. For this reason it is important that the weights and the contribution values be well defined so that the model is ready at the time the decision support system needs to be used. An on-going research by the authors is focusing on a robustness analysis (as proposed by Roy [32]) of the TODIM-FSE and will be the subject of a forthcoming article.
This paper provides an alternative multi-criteria sorting method, to support the construction of decision models. The structure and procedures for application are fully described. A case study have attempted to illustrate how the constructed model may be put into practice. It is also possible to compare TODIM-FSE with alternative multi-criteria decision aid classification methods available. One well-known sorting approach is the ELECTRE TRI, described by Brito et al. [33] and Dias et al. [34]. In this method each alternative is compared with stable references, previously established by deciders. The AHP, described by Saaty [27] and the MACBETH, by Bana e Costa and Vansnick [35], were both originally constructed to solve ranking problems. However, it is also possible to use them to classify alternatives such as those described in Bana e Costa and Oliveira [36]. Using these methods the categories are built experimentally, together with decision makers, after the construction of the model. The borders for each category will depend on a set of previously defined alternatives or even on fictitious data, used by the deciders as references. Generally, a great deal of information is required in order to build the categories within these methodologies. A comparative analysis will reveal that in terms of the aforementioned elements, the TODIM-FSE is similar to the ELECTRE TRI method, in that each alternative is compared to a stable reference, set up by petroleum-study specialists. One significant characteristic of the TODIM-FSE method is its ability to solve the decision problem as presented in this article. This is because it is not common to have oil spills (and available information about them) and be able to evaluate the models constructed, according to the demands involved in the AHP, MACBETH and similar methods.

Another remarkable feature of TODIM-FSE relates to the possibility of merging elements from fuzzy logic and Prospect Theory. For, in this way, it is possible to take into account the imprecision commonly present in human judgments in the moment that the contribution functions are built. It is also important to underline the fact that knowledge of fuzzy logic would help to build the models themselves; however, this same knowledge is not needed to actually use the models. Thus, once the models are constructed by a decision analyst, the users will incorporate their preferences using scales without any fuzzy characteristic. This advantage undoubtedly contributes towards the comparative ease of using the TODIM-FSE method. The use of Prospect Theory, embedded in TODIM equations, allows the decision makers the possibility of considering risk in the decision problem. This is completely suitable for the oil spill situation presented in this article.
Finally, the TODIM-FSE model constructed and the applications in well-defined oil spill situation, have contributed towards verifying the quality of the method. Additionally, the feasibility of embedding the model within the SISNOLEO structure is apparent and applicable, in terms of assisting petroleum analysts in improving their decision-making regarding oil spills contingency actions.

References


