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A multiple criteria decision model for assigning priorities to activities in project management

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Abstract

This study presents a model for supporting project managers to focus on the main tasks of a project network using a multiple criteria decision aid (MCDA) approach. A MCDA structure is important for dealing with this kind of problem, in the context of the project manager, when he/she solving a decision problem, taking into account several, often contradictory, points of view. A case study on the construction of an electricity sub-station is used to demonstrate the model proposed. As a result, managers can increase their performance in controlling project activities, particularly in a dynamic and changing environment.
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1. Introduction

Construction project management is a difficult task, when one takes into account the complexity, uncertainties and large number of activities involved. The increasing complexity and uncertainty of construction projects have led to many significant losses for the construction industry. Problems related to the management of projects are addressed in many studies. Sambasivan and Wen Soon [1] present several causes for losses in construction project management, such as a contractor's faulty planning, inadequate contractor experience, problems with subcontractors, shortage of material, non-availability of and failures in equipment, lack of communication between parties and mistakes during the construction stage. Hameri [2] visualises other problems: lack of discipline in controlling design change, diverse views on what the objectives of the project are and poor reactivity to sudden changes in the project environment.

Some considerations on construction project management at the building site need to be emphasized such as the high degree of current uncertainty about the construction process, the predominance of excessively informal decision aid coming from the project manager and the exaggerated over-emphasis given by project managers to controlling time and costs [3]. According to Cooke-Davies [4] there have been several past studies on the success of projects and which factors lead to project success. Despite this, a project may still under-perform and an understanding of project success factors alone is not sufficient for the success of a project [5].

The role of the project manager and his/her leadership style have been addressed as important aspects for the success of a project [5], although most of the literature ignores this [6]. The project manager's monitoring of tasks and his/her relationship with subordinates seems to be direct related to the performance of the project.

Greek and Pullin [7] also assert that many construction project management teams do not focus on those critical issues of projects. Project management, according to these authors, is an activity characterised by failure and these failures happen for two basic reasons: technical uncertainty and misjudgement of a project's urgency.

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In the context of construction projects, the basic question to be considered is how the project manager can control and monitor the large number of tasks contained in the project schedule, since long term planning hardly ever occurs without any changes. In practice, project managers apply different managerial practices to each type of project task, as they cannot give the same attention to all tasks. Hua Chen and Tau Lee [8] assert that a project manager's performance is directly related to his/her managerial practices. In their study, a performance evaluation model for project managers was constructed considering leadership behaviours that lead to managerial practices which contain some essential factors that may affect them.

Thus, this paper presents a more structured model for supporting the project manager so as to focus his/her attention on the main tasks of the project network. The identification of these main tasks is attended to by using multiple criteria decision aid methods (MCDA), in order to evaluate simultaneously the several aspects related to the performance of projects such as: deadlines, costs, contractors' experience and so forth. A case study on the construction of an electricity sub-station was carried out to demonstrate the structured model proposed.

2. Characterization of problem

Projects need to be divided into parts that admit to being manageable. This means defining a set of activities or tasks that are very often inter-related. In construction projects, any given set of activities is usually very large and complex.

In general, different forms of management are applied subjectively to each set of activities (or tasks), without prior assessment of the activities or a study being made of the problem, such decisions being based only on the manager's experience. An analysis of this decision problem can help tackle each of these activities by using appropriate management methods, as a function of the specific instances of the activities and thus permitting better use of the manager's knowledge, acquired from his or her experience on previous projects.

Different classes of managerial practices should be defined and used when executing and controlling project activities. These practices are different because the possible associated consequences do require so, for instance:

- A group of activities may require a tighter form of managerial practice, for example, tasks involving subcontractors where the probability of delay is high. This could represent the possibility of a very undesirable consequence for the project. In such cases, the manager would perform the activities himself.
- On the other hand, another group of activities could require a standard form of managerial practice. They might be delegated to a subordinate, in order to keep the project operational as scheduled.
- The project manager could also delegate another group of activities to a subordinate, but in this instance with very close monitoring by him/her. This close monitoring could be necessary with regard to the possibility of a medium undesirable consequence.

Classifying tasks into types of managerial practice are dependent on the context of the problem and should be driven by the project's objectives. Therefore, several criteria are considered for this purpose.

3. Proposed model structure for assigning priorities to activities in project management

The structured model proposed aims to assign project tasks into three classes of managerial practice, based on their characteristics in relation to a set of criteria. The application of the model requires two procedures with the aim of obtaining a general view of the problem and to regularly reassess the model.

The initial procedure consist of five steps presented below, and analyses all project activities without considering their inter-relationship only as an important basis for thinking through the problem.

1. Building activity networks
2. Managerial classes: definition
3. Set of criteria: definition
4. Assessment of activities for each criterion
5. Applying a multiple criteria method in order to classify activities.

The activity networks are used as a way of producing information for the proposed model. The use of the program evaluation review technique (PERT) allows the network to be determined making use of probabilistic judgments about the duration of the project. Methods like PERT and CPM are widely advocated techniques [9–11]. However, others network models, such as critical path method (CPM) could be applied.

Using project information at hand, the manager should define the classes of managerial practices. This definition is context dependent. For instance, three classes of managerial practices can be considered such as those presented in the previous section. Fig. 1 shows this classification problem.

The structure of the problem also involves the requirements for defining each class of managerial practice. It is related to the set of criteria to be considered in the evaluation process and configures one of the most important parts of the analysis. This set of criteria will be related, in some way, to the project manager's view about the objectives of the project. For instance, one can consider criteria such as: task cost, resource mobilization (supply contractor), duration (length), slack, security, variability (measured by the deviation and used when a probabilistic time estimate is used), number of successor activities based on the inter-relation dependence.

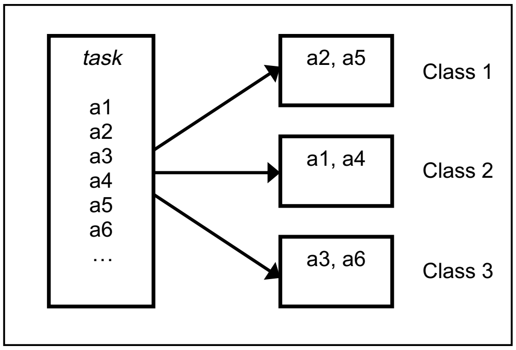

Fig. 1. Classifying tasks into three managerial practices.

Various methodologies can be used to support compiling the set of criteria of the decision problem. Examples are: *post-it* sessions, constructing cause and effect diagrams, use of cognitive maps, constructing value trees, and so forth (details about these techniques can be found in Belton and Stewart [12]).

The multiple criteria decision aid method is then applied to assign each activity (or task) into a specific class of managerial practices. A central aspect of this proposed structured model is the process of choosing the MCDA method to be used. This choice should involve analysing the context of the problem, the actors and their preference relation structure. The context of this problem is a classification of tasks, as presented in Fig. 1. The decision-maker's preference (his/her rationality and sensitivity to the imprecision of data) is an important aspect that should be taken into consideration when choosing a method.

The application of this initial procedure will provide a better understanding of the problem and some insights from the model. The model must be reassessed so as to consider the dynamic and changing environment.

3.1. Reassessments of the model

The proposed model must be applied at regular intervals (weekly, monthly, other) and the only activities analysed are those of that specific period. In other words, the model must be used periodically, in accordance with the length of the project.

It is understood that the model must be re-assessed periodically because changes may take place when carrying out project activities. Due to the uncertainties of the planning process, it may be necessary to reprogram all or part of the set of project activities, that is, to re-plan. In this case, it may well be necessary to re-think the objectives and to put forward a new schedule of activities. This is an interactive feature of planning and controlling projects. The structure proposed can be visualized in Fig. 2.

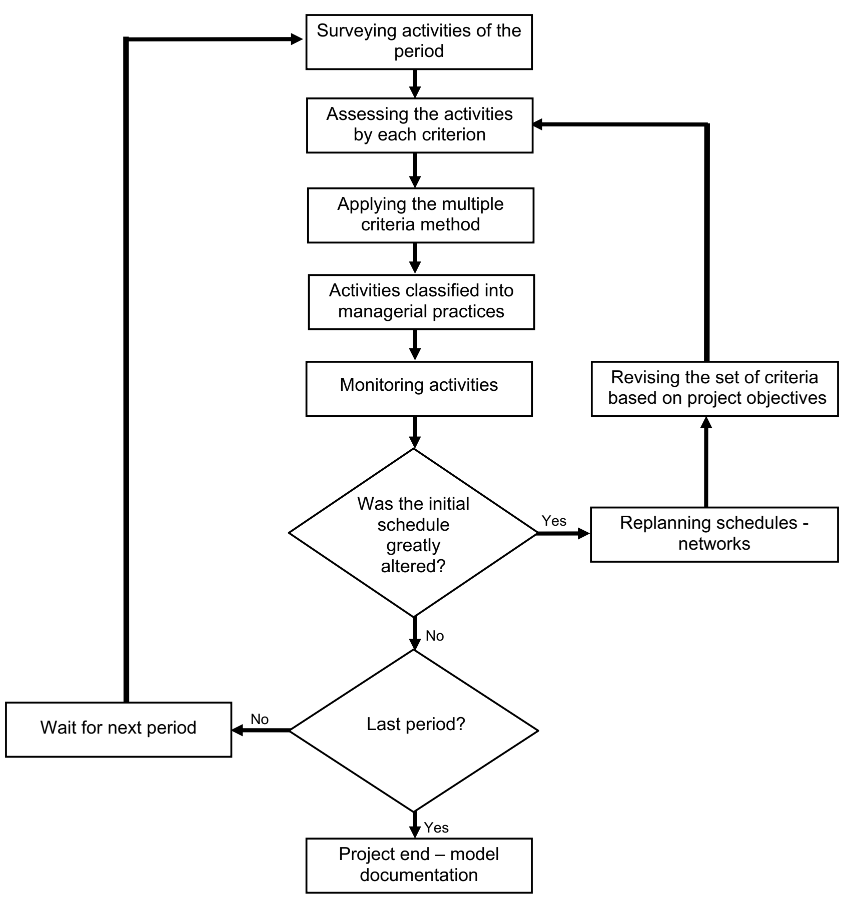

Fig. 2. Multiple criteria decision aid structure – reassessment of the model.

For each period of evaluation, a new set of tasks (or activities) is assembled and the data should be updated. The evaluation of the activity over a specific period (p_i, $i = 1$ to p) is used to account for the changes which occurred in the previous period (p_{i-1}). As an example, these changes can occur if some activity is delayed or new information and/or constraints are added in the process of carrying it out. In addition, some adjustments to the multiple criteria decision making method may be necessary, such as changes to parameters. When significant changes occur it may be necessary to re-plan.

The application of the proposed structure should be continuous until the conduct of the project ends. In other words, a new period is started after monitoring the conduct of the previous period and the process is repeated until all periods are finished.

As a result, the manager will make better use of his or her time through sound managerial practice for each type of task and thus be able to focus on the most relevant activities which need greatest attention.

4. Multiple criteria decision aid methods

The MCDA area has a large set of tools the purpose of which is to help the decision-maker solve a decision problem by taking into account several, often contradictory, points of view. In general, multi-criteria decision-aid methods are divided into three large families [13]: unique synthesis criterion, consisting of aggregating different points of view into a unique function which must subsequently be optimised; the outranking synthesis approach, using methods which aim first to build a relation, called an outranking relation, which represents the decision-maker's strongly established preferences, given the information at hand; and the interactive local judgment approach, proposing methods which alternate calculation steps and dialogue steps.

The outranking synthesis approach has been applied to build the proposed model. The elimination and choice translating algorithm (ELECTRE) method is widely examined in the literature [12–14]. The choice of the method is an important issue discussed in the topic choosing the multicriteria method.

Multiple criteria decision aid methods (MCDA) have been applied to a variety of problems, such as maintenance outsourcing [15], maintenance strategy [16], water supply management [17], project risk assessment [18], multi-criteria risk analysis [19], service outsourcing contracts [20] and construction bidding [21]. Mian and Dai [22] show the main decision problems related to project management to be resource allocation, prioritising the project portfolio, selection of managers, budget evaluation and selection of salespersons.

5. Case study

An application in construction of an electricity sub-station is used to demonstrate the ideas behind the model proposed. A simulation is undertaken which considers only the initial procedure, since the real application is too extensive and is not the objective of this paper.

The process of constructing a sub-station can be very complex as it involves the participation of various departments – internal to the organization – besides the participation of other external organizations. Due to the large number of activities and sectors to be managed, it is interesting to conduct an initial macro study and, thus, to detail those activities which need tighter management.

5.1. Structuring the problem

The project for constructing the electricity sub-station was divided into four phases: design, supplies, construction and commissioning. These phases were broken down into activities as shown in Table 1.

In this problem, the project manager wishes to classify the whole set of tasks into three classes according to different managerial procedures (see Fig. 1). The three managerial classes were defined as follows:

- Class 1: delegation to a subordinate without close monitoring
- Class 2: delegation to a subordinate with close monitoring
- Class 3: management of activities by the project manager himself/herself

5.2. Building the model: application of the proposed model

The structure proposed begins once the project schedule is established and the inter-relations of the activities are visualized. Thereafter, the process of thinking about the set of criteria takes place. Therefore, initial consideration was given to the following factors:

- Qualified staff involved: refers to the need to involve highly-qualified technical staff in different areas.
- Mobilizing resources: difficulty in mobilizing resources, i.e. in assembling and allocating the resources needed to conduct the activity.
- Experience in conducting the activity: represents the experience prior to the activity, or the set of information which exists on the activity.
- Cost: total cost of conducting the activity.
- Degree of impact on commissioning: the degree of impact on commissioning represents the possibility of the activity presenting problems in the commissioning phase.

All of the criteria, except the cost criterion, are measured on the decreasing ordinal scale 1;3;5;7;9. (the larger the number the worse situation). The assessment of the activities for each of the criteria considered is presented in Table 1.

Table 1
Construction activities for sub-station and assessment by each criterion

	Activities	Average length (days)	Predecessors	Experience	Staff	Cost (US$)	Mobilizing resources	Impact on commissioning
A1	*Start*	–	–	–	–	–	–	–
A2	*Sub-station project*	–	–	–	–	–	–	–
A3	Purchases report	30	A1	3	1	580.00	3	1
A4	Choice of site	29.97	A1	7	5	1,150.00	3	1
A5	Basic project	22.23	A1	5	9	5,800.00	1	1
A6	Acquisition of the site	11.40	A4	3	3	1,150.00	3	1
A7	Executive project telecomm.	31.10	A4	3	9	11,550.00	3	7
A8	Executive project civil	27.73	A4;A5	3	9	11,440.00	3	1
A9	Executive project electromechanical	30.00	A4;A5	3	9	11,450.00	3	7
A10	Executive project MPCC	40.57	A5	5	9	11,500.00	5	9
A11	Specification of service contract	10.57	A7;A8;A9;A10	3	9	1,140.00	3	7
A12	*Supplying the sub-station*	–	–	–	–	–	–	–
A13	Acquisition of components	40.57	A3	7	1	114,400.00	7	5
A14	Formalizing the acquisition of site	38.93	A6	9	5	114,450.00	1	1
A15	Contracting construction	38.90	A11	5	5	114,395.00	7	1
A16	*Construction of the sub-station*	–	–	–	–	–	–	–
A17	Earthwork	28.90	A14; A15	3	5	57,200.00	3	1
A18	Installing the ground grid	20.00	A14; A15	1	9	57,250.00	7	3
A19	*Milestone earthwork*	–	–	–	–	–	–	–
A20	Bases	20.57	A19	3	7	57,185.00	3	1
A21	Command post	22.77	A19	3	7	114,425.00	3	1
A22	Access road	40.57	A19	5	5	34,320.00	1	1
A23	Conduits	38.33	A19	3	9	11,440.00	1	3
A24	Equipment	22.77	A13; A20; A21	3	9	993,030.00	7	9
A25	Setting up MPCC	26.10	A13; A21; A23	7	9	302,030.00	9	9
A26	Busbars	17.27	A13; A20	5	7	915,253.00	3	3
A27	*Commissioning the sub-station*	–	–	–	–	–	–	–
A28	Commissioning ground grid	3.16	A18	1	5	22,880.00	1	1
A29	Commissioning equipment	5.50	A24; A28	1	7	22,890.00	3	1
A30	Commissioning the MPCC	7.16	A25	1	9	22,875.00	7	1
A31	Final commissioning	4.33	A29; A30	1	9	22,900.00	7	1
A32	*End*	–	–	–	–	–	–	–

5.3. Choosing the multi-criteria decision aid method

In this study, the ELECTRE TRI [23] method is used in order to classify activities into a set of different managerial classes according to some norms. Its use is justified by the complexity of the problem, its context (classification) and the imprecision of the data, and in order to be able to insert the subjectivities into modelling the problem.

The ELECTRE TRI method is part of a family of methods called ELECTRE. The family comprises the methods ELECTRE I, II, III, IV, IS and TRI, each of which was developed to tackle a different problematic (selection, ranking and classification). The ELECTRE methods are often used in contexts where alternatives have been assessed on criteria with ordinal and ratio scales.

The application of ELECTRE TRI method can be divided into two main steps (readers are invited to consult Mousseau and Slowinski [24] and Dias and Mousseau [25]):

(i) Defining the parameters of the model (category profiles, weights and thresholds);
(ii) Investigating the model in order to give a classification.

5.3.1. Defining the parameters of the model

The central aspects when implementing the proposed model concern the process of thinking about the weights of the criteria and the requirements of the categories. The latter are represented by the limits for each criterion (b_1 and b_2) and will distinguish the three classes of managerial practice. For example, the decision-maker should feel comfortable in stating that class 1 should contain activities that cost more than 15% of the total project cost.

Eliciting these parameters is one of the main difficulties that an analyst must face when interacting with a decision-maker [24]. Those parameters can be established by means of interviews and discussions about the problem. Table 2 shows the values of the parameters.

It is important to stress in the ELECTRE TRI method that the weights represent the relative importance of the criteria, and play the same role as a number of votes in

Table 2
Assessment of parameters of model by each criterion

Criteria	Weight	Profile b1	Profile b2
Qualified staff involved	0.15	3	5
Mobilizing resources	0.20	5	7
Experience in conducting the activity	0.15	3	7
Cost	0.30	10,000	50,000
Degree of impact on commissioning	0.20	3	7
Criteria		$(b_{1(cost)})$	$(b_{2(cost)})$
q(Cost) - indifference threshold for criteria cost		1,500.00	7,500.00
p(Cost) - preference threshold for criteria cost		3,000.00	15,000.00
v(Cost) - veto threshold for criteria cost		6,000.00	30,000.00

a voting procedure. The meaning of the weights changes according to the MCDA method considered. In an additive method, such as the widely used AHP method (analytical hierarchy process method) [26], the interpretation of the weights is completely different; weights of scaling constants are equivalent to those for substitution rates: if the unit of the criterion changes, its weight changes [13].

Having defined the weights, the threshold parameters should be established. The parameters for indifference, preference and veto threshold were only considered in the quantitative criterion cost. These values are also presented in Table 2. The assignment of each activity to a category is established if the outranking relation is validated. This means that an activity A_1 is assigned to a category C3 if the credibility index $\sigma(A_1,b_2)$ is greater than a cut-off level λ, $\lambda \in [0.5, 1]$.

As an initial analysis, the cut-off level λ was fixed in 0.7. This means that the manager's preferences indicate that for classifying one activity in a specific category, the activity needs to satisfy about seven percent of the norms defined for that category. Despite this initial definition, the manager is free to vary this index and to analyse the results.

5.3.2. Investigating the model

The stage of investigation provides the results of the model, in which tasks are classified. Within this general vision, most of the activities were assigned to class 1 and class 2. The activities A3, A4, A5, A6, A8, A11, A14, A17, A20, A21, A22, A28, A29, A30 and A31 can be delegated to a subordinate and the activities A7, A9, A10, A13, A18, A23 and A26 should also be delegated to a subordinate but now with close monitoring.

Only three activities were classified in class 3 (management of the activity by the project manager himself/herself). Activity A15 (contracting construction) presents a very high level of difficulty in mobilizing resources, which can lead to delays in the project schedule. Activity A24 (equipment) is associated with a very high cost, to such a degree that it has a strong impact on the project budget. On the other hand, activity A25 (setting up MPCC), besides having a high cost, also presents a low level of experience.

The decision-maker (project manager or officer-in-charge) should carry out a sensitivity analysis, varying the values of the weights and the model's parameters in order to have a better understanding of the implications of these values in terms of the output from the model. In this study, the weights were varied by about 10% and the model kept the same recommendation, implying the classification is reliable.

The application presented here is only a general view of the model. The real benefits of the model are obtained by reassessing it periodically, considering only one group of tasks for that period and after updating the data for the successive periods.

6. Concluding remarks

Throughout the process of conducting the project, the activities classified in class 3 merit greatest attention from the project manager, as these are the ones that meet the norms specified for that category, and can cause negative impacts in terms of the project's objectives.

This study also allows the manager to be more effective in managing projects in a dynamic environment, as he/she can use the managerial practice appropriate to each type of task and thus focus efforts on aspects that really matter. In this case study, the project manager will not be involved in performing tasks related to purchase reports. The use of the model is also very important when the project manager is involved in a multiple project environment. So, having applied the proposed decision structure and considering all the periodic re-assessments of the model, the project manager has the option to anticipate the problems that may occur and draw up contingency plans at the time when the preceding tasks are still being carried out.

The model developed requires the involvement of the whole project team in order to keep information up-to-date and to carry out the constant reassessments of the model. Therefore, the use of a decision support systems DSS and an integration system to facilitate communication between teams is very helpful for applying these techniques.

Finally, the greatest benefit to be derived from applying the multiple criteria decision structure to construction projects is in order to analyse the problem better and to provide a well-structured model that can consider several criteria simultaneously. This model prompts project managers into thinking about the trade-offs among project objectives.

Contribution of multicriteria method on project management practices has been shown to be a very useful. Several other models in this contexts may be developed in order to insure a formal approach for the project management practice. Future work may be conducted regarding exploring other different methods and their particular requirements associated with the projects demands. Also, different kind of problems may be analysed, such as: decision problems related to risk management could be conducted taking into account multiple objectives.

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References

[1] Sambasivan M, Wen Soon Y. Causes and effects of delays in Malaysian construction industry. Int J Project Manage 2006;25(5):517–26.
[2] Hameri Ari-Pekka. Project management in a long-term and global one-of-a-kind project. Int J Project Manage 1997;15(3):151–7.
[3] Laufer A, Howell G. Construction planning: revising the paradigm. Project Manage J 1993;24(3):23–33.
[4] Cooke-Davies T. The "real" success factors on projects. Int J Project Manage 2002;20(3):185–90.
[5] Pheng LS, Chuan QT. Environmental factors and work performance of project managers in the construction industry. Int J Project Manage 2006;24:24–37.
[6] Turner JR, Muller R. The project manager's leadership style as a success factor on projects: a literature review. Project Manage J 2005;36(1):49–61.
[7] Greek D, Pullin J. Overrun, overspent, overlooked. Prof Eng 1999;12(3):27–8. Bury St. Edmunds.
[8] Hua Chen S, Tau Lee H. Performance evaluation model for project managers using managerial practices. Int J Project Manage 2007;25(6):543–51.
[9] PMI. A guide to the project management body of knowledge – PMBOK GUIDE: Project Management Institute; 2004.
[10] Maylor H. Project Management: paperback; 2002.
[11] Turner J. The handbook of project based management: improving processes for achieving your strategic objectives. New York: McGraw-Hill; 1999.
[12] Belton V, Stewart J. Multiple criteria decision analysis – an integrated approach. London: Kluwer Academic Publishers; 2002.
[13] Vincke P. Multicriteria decision-aid. Bruxelles: Wiley& Sons; 1992.
[14] Roy B. Multicriteria methodology for decision aiding. Netherlands: Kluwer Academic Publishers; 1996.
[15] Almeida AT. Multicriteria modelling of repair contract based on utility and ELECTRE I method with dependability and service quality criteria. Ann Oper Res 2005;138:113–26.
[16] Almeida AT, Bohoris GA. Decision theory in the maintenance strategy of a standby system with gamma distribution repair time. IEEE T Reliab 1996;45(2):216–9.
[17] Morais DC, Almeida AT. Group decision-making for leakage management strategy of water distribution network. Resour Conserv Recy 2007;52(2):441–59.
[18] Zeng J, Min An, Smith NJ. Application of a fuzzy based decision making methodology to construction project risk assessment. Int J Project Manage 2007;25(6):589–600.
[19] Brito AJ, Almeida AT. Multi-attribute risk assessment for risk ranking of natural gas pipelines. Reliab Eng Syst Safe 2008. doi:10.1016/j.ress.2008.02.014.
[20] Almeida AT. Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method. Comput Oper Res 2007;34(12):3569–74.
[21] Seydel J, Olson DI. Multicriteria support for construction bidding. Math Comput Model 2001;34(5):677–701.
[22] Mian SA, DAÍ CX. Decision-making over the project life cycle: an analytical hierarchy approach. Project Manage J 1999;30:40–52.
[23] Yu W. Aide multicritere a la decision dans le cadre de la problematique du tri: methodes et applications. PhD thesis, LAMSADE, Universite Paris Dauphine; 1992.
[24] Mousseau V, Slowinski R. Inferring an ELECTRE TRI model from assignment examples. J Global Optim 1998;12:157–74.
[25] Dias LC, Mousseau V. Iris: a DSS for multiple criteria sorting problems. J Multi-Criteria Dec Anal 2003;12:285–98.
[26] Saaty TA. The analytic hierarchy process. Pittsburgh: RWS Publications; 1990.