Multicriteria methodology and hierarchical innovation in the energy sector

The Project Management Institute approach

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Abstract

Purpose – The purpose of this paper is to state a hierarchy methodology to select the most promising innovative projects, based on the processes defined by the successful Project Management Institute.

Design/methodology/approach – Open innovation is a new option for companies to acquire knowledge; however, in a changing and global market, it is necessary to define and select properly the proposals to be financially supported. A proven multicriteria decision methodology (MCDM) is recommended in this case to hierarchize alternatives. Moreover, analytical hierarchy process (AHP) has been considered in this study as a proven and simple MCDM.

Findings – AHP has been demonstrated as a suitable option to evaluate innovative project proposals, thanks to its integration with the Project Management Institute methodology. A process example has been included to demonstrate its application.

Research limitations/implications – Innovative projects and project proposal selection have always implied subjective criteria. Moreover, some of the processes defined in the methodology were not well defined in the project proposal.

Practical implications – The management of a project portfolio in a rational way would help decision makers to fund the most promising projects/alternatives under consideration. In this way, the inherent risk of R&D projects would be minimized.

Originality/value – The management of a portfolio of innovative proposals is less often addressed in the literature. This paper focuses on the hybridization of the criteria and processes described in the PMBOK Guide and an MCDM.

Keywords Projects, Process innovation, Energy industry, Innovation projects, Multicriteria methodology, Project Management Institute

Paper type Research paper

Introduction

Energy model is undergoing a continuous transformation toward the system decarbonization: both in the electricity generation and the transport sector. For energy governance, it is critical to know how to manage a complex “energy trilemma” which involves competing demands of energy security, climate change mitigation and competitiveness (especially in developed countries) (World Energy Council, 2016; Gunningham, 2013; Heffron *et al.*, 2015).

In the energy market, innovation, considered a process of value generation, allows companies to maintain or increase their position in the market (Abernathy and Clark, 1985). Innovation management has become more flexible (Markham and Lee, 2013), considering not only the innovation generated by the company itself, but also – and in a more prominent way – open innovation (OI). OI proposes a new innovation strategy whereby companies go beyond their limits and develop cooperation with external organizations or professionals to improve efficiency in innovation processes (Figure 1).

But how to deal with the projects evaluation in a hyperconnected world with accelerated technological changes? Facing the proliferation of innovative projects, it is necessary to

Figure 1.
Logical framework of
any project and open
innovation approach

establish a methodology that allows companies to select which of them offer more guarantees of success or return on investment. Decision support tools allow the selection and hierarchy of different alternatives – in this case, research proposals – according to a series of criteria (Enea and Piazza, 2004; Subramanian and Ramanathan, 2012).

Methods of multicriteria-based selection, supported by mathematical algorithms, enable the evaluation of both quantitative and qualitative criteria. In general, these methods can be classified according to multi-objective decision making or multi-attribute decision making. This methodology considers a series of alternatives in front of a series of attributes or criteria. The best option is usually selected by comparing each of the criteria against the alternatives (Pohekar and Ramachandran, 2004; Saaty, 2006).

In the energy sector, these techniques have been applied routinely for the selection of different alternatives (San Cristobal, 2011; Schmoldt *et al.*, 2001), with the analytical hierarchy process (AHP) methodology enunciated by Saaty (1977), one of the algorithms widely used in decision making. AHP allows to approach the decision making considering a breakdown and a comparison between criteria to determine weights and values. Even if analytical network process (ANP) admit dependent criteria (Saaty, 1996; Cheng and Li, 2004; Nisel and Özdemir, 2016), in this case, the whole process considered consists of independent criteria, as it is defined by a well-known methodology. Other methods were reviewed in this study, such as Promethee (Olson, 2001) and Vikor methods (Opricovic and Tzeng, 2004).

Literature review and hypothesis development

Energy sector and innovation

The transformation of the energy system goes through a redefinition of the principle of sustainability, based on three principles: environment, competitiveness and certainty of supply.

This technological development will be based on the technology evolution which includes advances in the three sustainability vectors. Technologies such as distributed energy, smart grids, renewable energy load factor, energy storage, CO₂ capture and storage are, among others, necessary technologies and their development depend on fulfilling the above-mentioned objectives. This fact makes the energy sector a propitious sector for the implementation of the OI approach.

Open innovation

OI concept is defined as an innovation process, whereby internal and external ideas are combined in systems and processes where the requirements are defined by a business model (Kratzer *et al.*, 2017). It consists of a new innovation strategy in which companies open their innovation process abroad by collaborating with external agents who play a leading role (Gobble, 2016).

In this concept, instead of having a closed innovation system, where the knowledge and the means belonged exclusively to the organization, it is proposed to open the process to universities, research centers or third parties, facilitating a new way of collaboration with external entities.

OI has been consolidated as an essential process, as markets have become more dynamic and unpredictable, where a technological, hyperconnected world allows the circulation and acquisition of knowledge in a broad and freeway. Open projects like Linux, Wikipedia and other engineering software such as gvSIG, openDtect, among others, are references in their sector in terms of collaboration and innovation development.

During the last few years, much has been written about how companies should implement this concept (Chesbrough, 2003), what recommendations can be made to apply in all fields, what is the role of communities and users in the IO (Chiaroni *et al.*, 2011) or what are the future perspectives of this concept that seems to have arrived to stay as a solid innovation alternative (Randhawa *et al.*, 2016; Huizingh, 2011). In recent years, research has been done on the application of OI in engineering (Saaty, 1980) and more specifically in the energy sector (Randhawa *et al.*, 2016; Wallin and Von Krogh, 2010). Recent articles put the focus of OI success on people and the corporate culture (Greco *et al.*, 2017).

In this context, the application of OI in the energy sector is already being investigated as a solution to unite the different stakeholder interests such as academics, governments and companies (Kratzer *et al.*, 2017) (Figure 2).

Project management methodology (PMP)

The PMP methodology defines project management as “the application of knowledge, skills, tools and techniques to project activities to meet project requirements” (Project Management

Figure 2.
Open innovation
concept: the process to
incorporate and
develop innovative
projects: value
creation process

Institute (PMI) webpage). A project is mainly based on three requirements: time, cost and scope. Although it is essential that the three of them are always completed, the PMP methodology establishes that there are additional requirements also necessary for the project to be fulfilled properly. These requirements are: integration, procurement, human resources, risk, quality and communication.

In the case of innovative projects, the previous methodology is equally applicable, adapting it to the intrinsic characteristics of these projects as detailed in different studies. Increasingly, it can be seen examples of the application of PMP tools in the case of integrated management of innovative projects, referring to similar processes such as planning, budgeting, control and monitoring or innovation project closure, among others (Wallin and Von Krogh, 2010).

Tools to support decision making: multicriteria algorithms

Multicriteria evaluation and decision-making methods include selection between a set of alternatives, optimization with several concurrent objective functions, and decision-making, rational and consistent evaluation procedures (Greco *et al.*, 2017). These methods allow the valuation of both quantitative and qualitative criteria and, in general, alternatives are classified according to whether the decision making is multi-objects or multi-attributes. In this case, alternatives vs attributes or criteria have been considered and the best choice is based on the comparison between the different alternatives (Saaty, 1977).

These methods do not consider the possibility of finding an optimal solution but, depending on the preferences of the decision agent and predefined variables and objectives, the development of the main problem will be to select the best alternatives or accepting alternatives that seem good and reducing the value of those that look bad, so that the final result is a classification of the alternatives under consideration (Saaty, 2006).

Among the procedures and mathematical algorithms considered, the AHP method stands out. The advantages offered by this methodology are simplicity and clarity (Saaty, 1977). The AHP decomposes the main problem through a hierarchical structure, allowing a detailed analysis of each of the levels of criteria considered (Figure 3) (West *et al.*, 2014). The method uses pairwise comparisons to measure the impact of items on one level (Liberatore and Nydick, 2008). The number of items in each level should be at least two but less than seven (Ishizaka and Labib, 2011).

In addition, AHP makes possible to perform the sensitivity analysis and to study other possible solutions by making changes in the relative weights that define the hierarchical structure. The AHP methodology offers three basic functions: the capacity for decomposition of the problem, an assessment based on a scale and the capacity for synthesis (Thomas *et al.*, 2013).

Figure 3.
Hierarchical structure
of AHP levels

The weight assignment for each criterion is established based on the construction of a series of matrices that must comply with the following axioms: reciprocity, homogeneity and priority.

Purpose of the study

The use of multicriteria algorithms for decision making in the energy sector is common (Sipahi and Timor, 2010), both for the selection of projects location of natural gas storage (Çetin Demirel *et al.*, 2017), and for incipient cases of study, like the geological storage of CO₂ (Llamas and Cámara, 2014) or the storage of compressed air in the subsoil (Llamas *et al.*, 2017). Furthermore, the ANP methodology has also been proposed for the selection of R&D projects (Henriksen and Traynor, 1999; Meade and Presley, 2002; Mohanty *et al.*, 2005; Cheng and Li, 2005) and other management issues (Chen *et al.*, 2012). The practice of project portfolio management as a rational decision process is necessary to define properly the criteria which should be considered.

In order to evaluate the attractiveness of project proposals, appropriate criteria should be determined. The identification of these criteria will be carried out in the present study, considering the methodology described in the PMBOK guide for project management issued by Project Management Institute (PMI) (2017), which has become the most recognized professional certification in project management. Thanks to this proven methodology, where independence process has been defined, AHP methodology is the most widely recommended multicriteria decision methodology. This approach has never been considered despite being a recognized way to evaluate project proposals.

The PMI proposes to consider the feasibility and execution of a project based on several constraints including scope, time, cost, risk, resources, quality and interest groups (PMI, 2017). It will be difficult to assess in depth all these variables and the interrelation between them to develop a realistic and achievable plan. Based on these constraints and uncertainties, it is possible to develop the areas of knowledge that will lead to the processes that take place in a project. The methodology proposed here allows evaluating innovative projects, from the beginning (idea) to the approval phase.

Therefore, the problem of prioritizing research projects poses several constraints, based both on internal and external criteria, which should be evaluated to select those innovative projects that are best suited to the company.

Once the selection tool was implemented, it was applied to a set of research proposals to prioritize those which were most attractive to be financed through private or public funds. The sequence recommended was the following:

- presentation of case studies;
- application of the methodology developed;
- ranking of results and prioritization based on the results obtained; and
- search for external financing.

Method

Mathematical hierarchization

The decision-making process was supported by algorithms based on multiple criteria which were used to select the best alternative among the projects evaluated. A number of mathematical algorithms have been developed for this purpose (Ho, 2008).

The AHP methodology is one of the most used algorithms (Zheng *et al.*, 2018), being applied to different solutions: planning, selection of alternatives, identification of resources, resolution of conflicts, optimization and others (Thomas *et al.*, 2013; Yazdi and Zarei, 2018;

Randelovic *et al.*, 2018). Among the advantages that this methodology provides are simplicity, the ease of use and great flexibility (Vaidya and Kumar, 2006; Patari *et al.*, 2018).

The proposed AHP method for evaluating project proposals in an OI environment is structured in the following phases:

- Description of the criteria considered: according to the processes described by the PMI methodology, the criteria considered are described and evaluated.
- Organizing the criteria in a tree structure: the criteria are structured by levels, until reaching the measurable one.
- Assignment of weights to each criterion: the assignment of weights to each criterion is constant for the evaluation of the alternatives. The weight assignment will be performed by pairwise comparison matrices, and the normalization of weights, according to the hierarchical structure constructed for this purpose.
- Assignment of values to measurable criteria: the final criteria of each branch should be measurable. With the aim of establishing comparisons between more than seven alternatives, the method proposes in this study the use of the AHP method in absolute mode. In this case, the alternatives are compared against a standard or reference model.

Each of the alternatives under study will be evaluated considering the model that will be constructed explicitly for this objective, considering the following equation:

$$A_1 = \sum_{i=1}^n W_i \cdot V_i, \quad (1)$$

which is the AHP equation for the evaluation of the alternatives under study.

Selection criteria

Technical criteria. For the definition of the criteria dependent on this block, it has been considered four criteria and processes described by the PMP (PMI, 2017).

Scope. It defines all the processes and works necessary to carry out the project. Among the most critical sub-criteria, it is important to highlight the following: management (how other processes will be carried out) and requirements (stakeholder needs); definition; and work structure through a decomposition of criteria.

Time. It is a key criterion in project planning. The following sub-criteria should be considered: definition of tasks and milestones (description based on the WBS described in the previous technical criterion); estimation of time, and necessary resources; and constraints imposed by resources or time.

Cost. There is a limitation in the decision-making process, even more in an OI environment. To study this, it has been considered the following sub-processes: cost planning – or how to estimate costs, budget development or control deviations; cost estimation, calculating the costs of each resource used to complete project activities; and economic tools – considering the internal rate of return, value at risk and the period of recovery of the investment (PRI).

Quality. When the objective reached in the project satisfies the needs for which it was undertaken. This includes regulated activities such as quality planning; quality manual according to ISO9000; and other sub-criteria such as customer compliance.

Organizational criteria. According to the PMP processes, another four criteria were defined in this block.

Human resources. In any type of projects, people have a fundamental role. Without them, nothing could be accomplished. Therefore, it is important to consider the staff that will develop the project. In addition, the different projects to be evaluated will have diverse requirements regarding staff structure and training. The sub-processes considered in this chapter will be the project director as a team leader, the team due to team motivation and leadership style are key to project success. In this case, there are three key aspects: roles identification within a team (e.g. using Belbin's theory), an appropriate leadership style (e.g. through the leadership situational theory) and the acquisition and development of the team, and the conflict management plan, defined as the tool that will ensure higher productivity and better decision making.

Communication. This is the main skill that a project coordinator should have. For the effectiveness of the communication, it is necessary to have a communications plan according to the need of the project, and proper manage of the information and its flow.

Risks. The innovation inherent in every project implies risk, which increases with the amount of innovation involved. In order to protect the investment, a series of sub-criteria are established that aim to evaluate this parameter: risk identification, analysis, response and monitoring.

The risks considered should be economic, technological and temporary, and the evaluation of them will be based on probability and impact (risk matrix).

Stakeholders. Achieving and maintaining interest in the project is one of the most delicate tasks: having both internal and external support is one of the project coordinator duties. According to the PMI, this process is described by planning, managing and controlling stakeholder participation.

Description of the alternatives. The School of Mining and Energy Engineering at the Universidad Politécnica de Madrid (UPM) offers a holistic training, where the technical aspects are complemented with transversal competencies such as creativity and innovation. Consequently, engineers are encouraged to present an innovative project in the last year of the Mining Engineering Master Program. Some of the project proposals have been included in this section; On the other hand, other projects have been selected because they have recently been approved by financial institutions and companies within the Project Engineering Laboratory.

Project A. Based on the CAES technology principle, it is proposed to apply in shallow geological structures and hybridizing thermal energy and geothermal storage technology. The idea is awarded by the contest of ideas acts UPM.

The principle consists on developing a cavity, in an optimum geological structure, with the purpose of accumulate energy in the periods of low demand of electric energy and generate electricity through the compressed air at the points of demand. The project proposes to relate storage energy with non-predictable renewable energy (mainly wind energy).

The execution time is 36 months, with a budget of €553.000.

Project B. It consists of an energy recovery system through the footsteps, as a strategy toward smart cities. The project proposes its use in tracks and sports area in cities. The trend for jogging is increasing, and so is the application of measures that are environmentally conscious.

The technical principle is based on tracks of any size formed by piezoelectric materials to transform mechanical energy into electricity. This energy will be stored in batteries for being used in public lighting near the runway and/or sports area within the city, with significant environmental benefit and reduction in the cost of electricity consumption.

The execution time is 21 months, with a budget of €338.000.

Project C. The project is based on the transformation of electric energy into hydrogen in the periods of excess production. To optimize hydrogen storage, the conventional gas pipelines will

be used. The combustion properties and decreasing contamination (release of CO₂, NO_X mainly), thus facilitating the hybridization of the currently disconnected energy networks. This proposal won a grant in the bidding contest by a company (UP4 Solutions Grant).

The execution time is 32 months, with a budget of €254.000.

Project D. Application of a closed-circuit geothermal heat exchange system located at the gas turbine air inlet in combined cycle plants.

By means of a reverse-cycle heat pump system, the energy is extracted from the inlet air to the turbine, thereby reducing its temperature. For this procedure, a coolant is used, capable of transporting the heat of the air to the subsoil through a geothermal probe of low or medium enthalpy.

With this reduction of the input air temperature (up to 8°C) to the turbine, the overall efficiency of the cycle is considerably increased, thus providing significant economic savings.

The execution time is 18 months, with a budget of €418.500.

Project E. Home delivery service using unmanned aerial vehicles (UAVs) as a means of transportation. The idea is basically to provide a fleet of UAVs to a hospitality company or home delivery company.

The UAV will be equipped with a geolocation system and will be controlled with software that transforms GPS coordinates into commands to move the UAV to the consumer and return. The UAV will also have a built-in box to enter the order in which there will also be a pressure sensor so that when the customer extracts, the product the UAV will resume the flight to the starting point.

The execution time is 12 months, with a budget of €165.000.

Results

According to the objective of selecting the most viable innovative projects among the alternatives in evaluation, the calculation model based on the multi-criterion AHP algorithm establishes the following steps in its resolution: assignment of values for each measurable criterion; construction of the model and structure of AHP criteria; and allocation of weights for each criterion.

To solve this model, the research team reflects the combined experience of more than 15 years of work in innovation and selection of ideas that could be implemented in successful projects. The presented results count on a structuring of values, allocation of weights and structuring and quantification of the measurable values.

The definition of criteria carried out in the previous sections of this paper has entailed the construction of a decision-making structure based on a decision tree (Figure 4) specific in this case for the objective pursued. This model allows to evaluate analytically the different alternatives under study and supports the decision agent through a consistent mathematical algorithm. The model must be detailed and structured, so that at the end of each node, the quantifiable criteria are described.

Weight assessment (W_i)

In this case, the AHP method is considered in each mode to establish a broad comparison of alternatives. In this case, one of the limitations of this algorithm is avoided: this establishes that the comparison of alternatives in relative mode (comparison of the alternatives with each other) should be limited to no more than seven. This constrain is known as consistency (mathematical limit) and neural limit (established by the impediment of the human brain to be able to compare elements simultaneously).

The application of the AHP model in absolute mode is to establish a comparison pattern. Here the pattern has been defined by setting the optimal values of each measurable criterion.

Note: Green blocks are measurable criteria

Figure 4. Hierarchical structure and selection of structures proposed for selection of innovative project – open innovation approach

In order to maintain consistency in acceptable levels, the AHP method proposes to consider the principles of reciprocity and transitivity through the following equation (Saaty, 2006):

$$a_{ij} = a_{ik} \cdot a_{jk}, \quad (2)$$

$$a_{ij} = 1/a_{ji},$$

which shows the principle to maintain the consistency of judgments, consistency: transitivity and reciprocity.

Comparison matrices (Equation 3) should be used to establish the weight of each criterion; these matrices are constructed in a sequential manner, where the level-to-level comparison is established, descending from level and relating the criteria

and weights according to the relation of nodes established in the decision tree (Figure 4):

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & \dots & 1 \end{bmatrix}, \quad (3)$$

Equation (3) shows the pairwise comparison matrix (AHP).

The weight of each criterion will be calculated using the following equation, where expert judgment is established using the maximum eigenvalue of the comparison matrix (Equation 3):

$$W_i = \sqrt[n]{\prod_{j=1}^n a_{ij}}, \quad (4)$$

Equation (4) shows the weight calculation using the AHP methodology.

Using this methodology, weights have been established for each measurable criterion, being represented by Figure 5. These weights will be applied equally in the evaluation of the alternatives so that an objective assessment of each alternative will be obtained.

Finally, and by way of verification, the sum of weights established for each measurable criterion must be 1, with the weight always being a value greater than 0, which is shown by the following equation:

$$\sum_{j=1}^n W_j = 1, \quad (5)$$

which shows the normalized weights.

Value assessment (V_i)

Taking into account the absolute AHP model, it is necessary to establish an optimal or maximum value for each of the measurable criteria. To do this, and in accordance with section 0, a structure of criteria has been established, considering in the second level the processes described in the PMI[®] methodology. At the end of each node, the measurable criteria are collected.

According to the tables described (Tables I and II), not only the scientific description of each criterion has been collected, but a mathematical assessment or scale has been attributed, being the value judgment of the decision agent transferred in a numerical value.

Application of the AHP model, evaluation of alternatives (A_i)

Priority is an abstract unit valid for any scale in which the individual's preferences are integrated with comparing tangible and intangible aspects.

The projects described in the previous section include the work developed in the Project Engineering Laboratory during the 2016–2017 and 2017–2018 academic years. Many of the projects collected are part of the work portfolio, while others are the result of working together with engineers of the Master of Mining Engineer.

The evaluation exercise focuses on the decision-making process on the financing of ideas and their development until the final presentation to the decision maker (see Figure 1). Table III shows the evaluation of the projects considered. As it is collected, the final

Notes: (a) Technical criteria; (b) organizational criteria

Figure 5.
Weights assessment

valuation of the alternative is presented in a disaggregated way considering the two criteria of the first level and the total of each alternative.

Thanks to this study, it is possible to select the most viable project, and moreover, it is possible to identify the strengths and weaknesses of the proposal in order to manage the consultation phase and/or clarifications in the decision-making process.

In this case, project A has the highest valuation among the considered alternatives. This project has clearly defined participation and structure of work and a detailed technical scope, which makes it an excellent project to be financed. On the contrary, the risk criterion has a medium or low valuation – evident in the “risk mitigation” criterion – which makes

Technical criteria	Secondary criteria	Quantifying criteria		
		1	5	9
Scope	Needs and expectations project	The traceability matrix is unclear or not well defined or does not exist. The requirements are not justified	The traceability matrix is clear and well defined, but missing documents	The traceability matrix is clear and well defined. All requirements are justified with relevant documentation
	Project scope plan	There is no scope management plan or requirements management plan	There is a scope management plan and a requirements management plan; but some of them are not well defined	There is a scope management plan and a requirements management plan; both are well defined
	WBS (work breakdowns structure)	There is no WBS	There is an WBS, but it is not complete	There is an WBS with all your defined work packages
Time	Tasks and milestones	There is no list of tasks or milestones	There is a list of tasks and milestones, but not all points are included	There is a list of tasks and milestones with all points included
	Time estimation	A precise estimation process has not been followed and it is very likely that there are significant deviations	An adequate estimation process has been performed but could have been more accurate	The time estimation method has been consistent and accurate. No significant variations are expected
	Schedule	There is no schedule or it is not detailed	There is a degree of detail according to a block diagram. There is no method of control	There is a degree of detail according to a Gantt chart. In addition, there is a method of controlling the same
Cost	Cost plan ^a	There is no cost plan	There is a cost plan, but not all points are defined	There is a perfectly defined cost plan
	Cost estimation	A precise cost estimation process has not been followed and it is very likely that there are significant deviations	An adequate cost estimation process has been performed but could have been more accurate	The cost estimation method has been consistent and accurate. No significant variations are expected
	Economic tools	No tools are used	At least two of the main economic tools (TIR, VAR, PRI) are used	All economical tools (TIR, VAR, PRI) are used
Quality	Quality plan	The standards to be used are not defined, nor their method of satisfaction	The standards to be used are not fully defined, there are deliverables that do not have a quality control plan	The standards to be used are completely defined, as well as their method of satisfaction
	Quality control	There is no method of quality control	There is a method of control, but some points are not defined or are not clear enough	There is a perfectly clear and defined control method
	Customer compliance	There is no method for customer compliance	There is a method for customer compliance, but there are potential implementation or procedural problems	There is a method of customer compliance; This is clear and effective

Table I.
Sub-criteria of selection quantifiable within the technical criteria

Note: ^aThe cost plan contains the planning, structuring and control of project costs as well as cost management processes (associated tools and techniques), details of project financing or project resources

Organizational criteria	Secondary criteria	Quantifying criteria		
		1	5	9
Human resources	Project manager (PM)	The PM leads for the first time projects of these characteristics or similar characteristics	The PM has directed similar projects, but not of these characteristics	The PM has already directed projects of these characteristics
	Team	There is no planning for the acquisition and training of the equipment	There is a planning for the acquisition of the equipment, but there is no planning of the training	There is both a planning for the acquisition and formation of the equipment
	Conflict management plan	There is no conflict management plan	There is a conflict management plan but it is not known how the staff will be communicated	There is a conflict management plan and the way in which the team is communicated is planned
Communication	Communication Plan	There is no information management plan	There is an information management plan, but some part is lacking (communication channel, format and contents of the type of information, people responsible for communicating, people who will receive the information, information technologies to use, frequency of communication, glossary of common terms)	There is a completely defined information management plan
	Information flow	There is no elaborate plan	There is an elaborate plan, but it is not clear enough and precise enough to inform the interested parties in time and form	There is an elaborate plan; Clear and precise way of informing the interested parties in a timely manner
Risks	Identification	There is no procedure or plan to know the risks that affect the project	There is a procedure and a plan, but it is not defined for all the factors that affect the project	There is a procedure and a plan, both totally clear and defined, for knowing the risks that affect the project
	Assessment	The risks identified are not valued	Risks are valued by impact and probability. The level of risk associated with these values is not known	Risks are valued by impact and probability. The level of risk is known thanks to the associated risk matrix
	Mitigation	There are no mitigation actions defined for the associated risks	There are mitigation actions defined for any of the associated risks	All associated risks have a defined mitigation action
Stakeholders	Planning	There is no procedure or plan to know the risks that affect the project	There is a procedure and a plan, but it is not defined for all the factors that affect the project	There is a procedure and a plan, both totally clear and defined to know the risks that affect the project
	Managing	There is no stakeholder management plan or communication plan	There is a stakeholder management plan, but there is no communication plan	There is a stakeholder management plan and a fully defined communication plan
	Controlling	There is no management plan for the requirements demanded by stakeholders	There is a management plan for the requirements demanded by stakeholders, but not all stakeholders have a defined plan	There is a fully defined stakeholder demand management plan

Table II.
Sub-criteria of
selection quantifiable
within the criterion
organizational issues

Table III.
Evaluation of the
alternatives (project
proposals)

WEIGHT		Wnormalized	A	B	C	D	E
Wtechnical	Needs and Expectations	0.098	9	5	5	5	1
	Project scope plan	0.033	9	5	5	5	1
	Work Breakdown Structure	0.020	5	1	5	3	1
	Tasks and Milestones	0.064	9	9	7	5	3
	Time estimation	0.064	5	3	7	5	3
	Schedule	0.021	9	9	9	5	5
	Cost plan	0.090	5	5	7	5	5
	Cost estimation	0.030	5	5	5	1	1
	Economic tools	0.030	5	1	1	5	3
	Quality plan	0.021	5	5	5	5	1
	Quality control	0.021	5	5	5	5	5
	Customer compliance	0.007	1	1	1	5	5
	Project manager	0.096	9	5	7	5	3
	Team	0.096	5	5	5	3	1
Worganizational	Conflict management plan	0.048	1	3	3	3	1
	Communication plan	0.066	9	9	9	5	5
	Information flow	0.022	5	5	5	5	5
	Risks Identification	0.057	5	5	5	1	1
	Risk Assessment	0.057	3	3	3	1	1
	Risk Mitigation	0.019	1	1	1	1	1
	Stakeholders planning	0.017	9	5	5	1	5
	Stakeholders managing	0.006	9	5	5	1	5
	Stakeholders control	0.017	1	1	1	1	1
	Technical		3.3	2.5	2.9	2.3	1.4
	Organizational		2.8	2.4	2.6	1.5	1.1
	TOTAL		6.1	4.9	5.5	3.9	2.5

this criterion one of the weak points having to be corrected in the updating of the reports consulted.

Among the projects consulted, projects C and B stand out because they present both technically and organizationally reasonable values – both projects have a positive evaluation from a technical point of view.

The results obtained by the algorithm proposed in this study were validated thanks to a professional and external evaluation: two of the most valuable projects were approved and financed by companies (project proposal A and C). Hence, the process of approval and validation of the algorithm considered the most robust and difficult evaluation: the industry.

In Figure A1, it can be found the mathematical development and matrices used to achieve the previous results.

Conclusions

In an external environment of the energy sector market where change is an accelerated event, derived from the political agreements derived from the fight against climate change, increased consumption and the need to guarantee supply at a competitive cost, it becomes necessary to establish innovation processes.

Not only OI allows to take advantage of the internal resources of a company, but also extends to all sectors and institutions related to innovation worldwide – the result of globalization derived from hyper-connectivity. This fact produces a difficulty in making decisions, derived from the huge response that can be received.

The use of standards that support decision-making process becomes a tool to increase competitiveness in the management of innovative projects: the selection of ideas and their development to financing is a process of high risk and consuming a long time.

The use of mathematical algorithms that support this decision making, and specially the use of the AHP model is demonstrated in this study as a useful tool for evaluating innovative projects.

Not only the decision making, but also allows establishing strong and weak points following one of the most recognized methodologies of project management worldwide and is the one developed by the PMI.

The application of this tool to a real and concrete case study, based on five examples, demonstrates its viability. The cases studied have not only been developed by students, but some of them are funded and are part of the project portfolio of the ETSIME-UPM Project Engineering Laboratory.

Next steps

As future work lines, it is proposed to consider an approach in which different interest groups propose another weights and the intersection of the valuations made with these weights is the most attractive point or alternative for their financing.

It will also be necessary to consider the degree of maturity of the project to be able to take into account projects that are mature, with a lot of input information, but also others in which the data are scarce and therefore the inputs of the matrix are limited, something that usually occurs in the initial stages of every project.

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Further reading

Stanko, M.A., Fisher, G.J. and Bogers, M. (2017), "Under the wide umbrella of open innovation", *[Journal of Product Innovation Management](#)*, Vol. 34 No. 4, pp. 543-558.

1st level					
Technical		Organizational			
Technical	1.00	1.00	2.00	3.00	
Time	1.00	1.00	1.00	3.00	
Cost	1.00	1.00	1.00	3.00	
Quality	1.00	2.00	2.00	1.00	
2nd level Technical					
	Scope	Time	Cost	Quality	
Scope	1.00	1.00	1.00	3.00	
Time	1.00	1.00	1.00	3.00	
Cost	1.00	1.00	1.00	3.00	
Quality	0.33	0.33	0.33	1.00	
	3.33	3.33	3.33	10.00	
3rd level Organizational					
	Human Resources	Communication	Risks	Stakeholders	
Human Resources	1.00	1.00	2.00	3.00	
Communication	0.33	1.00	0.87	2.90	
Risks	0.50	0.50	1.00	3.75	
Stakeholders	0.20	0.66	0.33	1.00	
	2.00	5.50	3.93	12.25	
2nd Scope					
	Needs and Expectations	Scope Plan	WBS		
Needs and Expectations	1.00	3.00	5.00		
Scope Plan	0.33	1.00	1.67		
WBS	0.20	0.60	1.00		
	1.50	4.60	7.67		
3rd Time					
	Risk and Mitigates	Time estimation	Schedule		
Risk and Mitigates	1.00	1.00	3.00		
Time estimation	1.00	1.00	3.00		
Schedule	0.33	0.33	1.00		
	2.33	2.33	7.00		
4rd level Cost					
	Cost Plan	Economic tools	Cost estimation		
Cost Plan	1.00	2.00	3.00		
Economic tools	0.33	1.00	1.00		
Cost estimation	0.33	1.00	1.00		
	1.67	5.00	5.00		
5th level Quality					
	Quality Control	Customer Compliance	Quality Plan		
Quality Control	1.00	1.00	3.00		
Customer Compliance	1.00	1.00	3.00		
Quality Plan	0.33	0.33	1.00		
	2.33	2.33	7.00		
3rd Human Resources					
	Project Manager	Team	Conflict Management Plan		
Project Manager	1.00	1.00	2.00		
Team	1.00	1.00	2.00		
Conflict Management Plan	0.50	0.50	1.00		
	2.50	2.50	5.00		
3rd level Communication					
	Information flow	Communication plan			
Information flow	1.00	3.00			
Communication plan	0.33	1.00			
	1.33	4.00			
3rd level Risks					
	Risks identification	Risks Assessment	Risks Mitigation		
Risks identification	1.00	1.00	3.00		
Risks Assessment	1.00	1.00	3.00		
Risks Mitigation	0.33	0.33	1.00		
	2.33	2.33	7.00		
3rd level Stakeholders					
	Stakeholders managing	Stakeholders planning	Stakeholders controlling		
Stakeholders managing	1.00	3.00	1.00		
Stakeholders planning	0.33	1.00	0.33		
Stakeholders controlling	1.00	3.00	1.00		
	2.33	7.00	2.33		

Figure A1.
Mathematical
development and
matrices for
evaluation of
alternatives