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A MCDM APPROACH FOR PROJECT FINANCE SELECTION: AN APPLICATION IN THE RENEWABLE ENERGY SECTOR

ANA GARCIA-BERNABEU
angarber@upv.es
Universitat Politècnica de València

FERNANDO MAYOR-VITORIA
mayor.fernando@gmail.com
Universitat Politècnica de València

FRANCISCO MAS-VERDU
fmas@upv.es
Universitat Politècnica de València

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ABSTRACT:

Renewable energy (RE) is emerging as a solution in order to replace fossil fuels and become the primary source of energy consumption. Investments in the RE sector involve huge amounts of capital but also many risks. Public sector plays an important role in promoting RE projects but due to the need for reducing public expenditure the private sector becomes essential in financing this type of projects. Project Finance is widely used in RE projects and is especially attractive to the private sector because it can fund major projects off balance sheet. The objective of this paper is to present a decision making tool for helping the private sector on the selection process of RE projects to be funded. The problem could be considered as a multiple criteria decision-making problem where both, financial and non-financial criteria have to be taken into account. Objective aggregation weights for those criteria are obtained using the Moderate Pessimism Decision Making approach and a final ranking of the projects is obtained.

Keywords : Project Finance, Renewable Energy Projects, Multi-Criteria Decision Making and Preference Weights.

RESUMEN:

Las Energías Renovables se están convirtiendo en una alternativa cada vez mas importante para reemplazar a los combustibles fósiles como fuente de energía. Los proyectos en el sector de las energías renovables implican grandes inversiones y también muchos riesgos. El sector público desempeña un importante papel para promover los proyectos de energías renovables pero debido a la necesidad de reducir el gasto público ha de recurrir al sector privado. Project Finance es un método de financiación ampliamente utilizado en este tipo de proyectos y resulta especialmente atractivo al sector privado porque permite financiar proyectos fuera de balance. El objetivo de este artículo es proponer un modelo de decisión multicriterio para ayudar el sector privado en el proceso de selección de proyectos de energías renovables que han de ser financiados con Project Finance. El método conocido como *Moderate Pessimism Decision Making* (MPDM) permite clasificar fácilmente alternativas desde varios criterios tanto financieros como no financieros de una manera objetiva .

Palabras clave: Project Finance, Proyectos de Energías Renovables. Teoría de la decisión multicriterio, Pesos preferenciales.

1. Introduction

Renewable energy (RE) has emerged as a long term solution for a sustainable, cost-effective and friendly source of energy generation for the near future. According to UNEP, renewables accounted for 43.6% of the new generating capacity installed worldwide in 2013, raising its share of world electricity generation from 7.8% in 2012, to 8.5% in 2013 [67]. However, the transition toward a low carbon-economy requires important investments from public and private initiative. While RE investments have received public support under the form of reduced taxes, direct subsidies or public incentives, private finance has so far played a marginal role [49]. This is due to investments in the RE sector are characterized by combining capital intensity with new technologies, which implies high returns but also high risks. Based on the European experience, limited bank lending capacities make the commercial banks unable to fund large projects with traditional loans.

Project Finance is a recent technique applied in large investments projects and its defined by Finnerty as “the raising of funds on a limited-recourse or nonrecourse basis to finance an economically separable capital investment project in which the providers of the funds look primarily to the cash flow from the project as the source of funds to service their loans and provide the return of and a return on their equity invested in the project” [26]. During the last decades of the 20th century Project Finance has enabled to provide financial solutions for large infrastructure, energy and environmental projects. From the project developers’ point of view Project Finance is usually chosen to reduce lender's recourse to the sponsors, permit an off-balance sheet of the debt and especially to reduce all types of project risks. Moreover, Project finance is a key element when transferring risk from the public to the private sector when there are high levels of public debt.

Research on new financing techniques for RE projects has gained interest in recent years due to the rising awareness of environmental issues. There is a wide number of contributions underlying the relevance of RE ([22], [23]). However, there is a lack of research on the financial aspects of RE projects [47]. The energy policy literature has seldom incorporated the investor's perspective. Given the relevance of considering a wide set of criteria to better understand the investor's preferences in the decision making process to evaluate Project Finance alternatives, we address the following question: Which RE projects do lenders prefer to finance? To answer this question, we propose a MCDM method as an exile tool to handle a wide range of variables. This is because traditional single criteria decision-making approaches cannot manage the complex analysis that a multi-dimensional space of different indicators and objectives involves [71], [72]. In RE projects, MCDM have been widely used in areas such as wind farm projects, geothermal projects, hydro-site selection and the main applications have been related to planning, RE evaluation, project selection, allocation and environmental issues [8], [69], [64]. In the context of selecting the best RE project to be funded using Project Finance, we apply the Moderate Pessimism Decision Making (MPDM) model to rank several real RE projects by analyzing the most important variables which can make a project succeed or fail [9]. The proposed methodology is a recent contribution in which preference weights are derived from an objective way.

The paper aims to make several contributions. First, to provide a better understanding of the Project Finance technique and its use in the RE sector. Second, to fill the gap of research on financial aspects of RE in the literature by reviewing contributions of MCDM to RE project evaluation from the investor's perspective. Third, the proposed MPDM model adds to the rational financial evaluation of investment opportunities a set of non-financial factors that affects the investor's decisions. Finally, within the illustrative example, we apply this multi-criteria decision making process to help banks to decide if they must join a project or not.

The remainder of the paper is structured as follows: First, we introduce the main features of Project Finance including the main agreements and participants. Second, we review the recent use of MCDM methods in RE projects. Third, we develop the theoretical bases of MPDM applied to RE. Finally, we develop an illustrative example.

2. Project Finance for RE projects

In 1992 the United Kingdom government implemented the Private Finance Initiative (PFI) as a way to involve the private sector in the provision of public services. This was a starting point for public-private partnerships (PPPs) as a financial mechanism to obtain private finance and satisfy the political need to increase investment in large-scale projects without affecting public borrowing. As stated by the World Bank, Project Finance is one of the most common financing arrangements for PPP projects.

Initially Project Finance has been used for high-risk infrastructure schemes, such as Oil & Gas, extractive (mining), transportation, telecommunications and energy industries. More recently and especially in Europe, Project Finance increased as the needs for public funding increased. The European PPP Expertise Centre shows that the main applications in Europe of PPP financing are, transport, public order and safety, general public services and the environment. Minor applications are education and healthcare. In the last two decades, Project Finance has played an important role in RE projects. However, non-recourse project finance in Europe sustained the biggest impact from the financial crisis with respect to on-balance-sheet finance [66].

Although there is no "standard" Project Finance structure, there are some typical features that appear in Project Finance.

- Lenders rely on the future cash flow of the project rather than the value of its assets.
- There is a specific company whose only business is the project, then this company is legally and economically self-contained, the so-called Project Company or the "Special Purpose Vehicle" Company (SPV).
- There are high levels of leverage, Project Finance debt covering 70%-90% of the total cost.
- It is a non-recourse or limited-recourse finance, that is, the lender has only a limited claim if the collateral is not sufficient to repay the debt.
- Risk is shared between all the parties of the project. A wide number of contracts or agreements provide support to the lenders in order to assure the future cash flows.

In Figure 1 the basic structure of Project Finance, with some participants and the corresponding agreements, is represented.

Project Finance differs from traditional finance as the lender primarily looks at the assets and revenue of the project in order to secure and service the loan. In Project Finance the lender has no recourse to the sponsors of the project. For the lenders it is important to identify, analyze, allocate and manage all the risk associated with the project. The basic principle of risk allocation is "Allocating all project risks to the most suitable participant whose risk preference is higher". Risk allocation is implemented through agreements between the project company and the rest of the participants and allows the project to be financed at low interest rates.

The robustness of Project Finance is based on these agreements, which assures the return of the project [8], [10], [27]. The rationale of such an agreement relies on the fact that the guarantor is the best at managing sales risks. The "off-take agreement" between the project company and the client involves that to the client assures a minimum level of sales paying for the balance if the amount of sales remains below this minimum level. In the Engineering, Procurement and Construction (EPC) Contract, between the constructor and the project company establishes that the project will be designed and built for a fixed price on a fixed date. In the "Put-or-pay" contract the supplier is obliged to purchase a minimum amount of inputs at a fixed price for a specific period, or to pay for the shortfall. Moreover, most projects are generally covered by several types of insurances, as for example, force majeure events, employer's liability, contractor insolvency and delays in obtaining permits. Other arrangements with the supplier (supply or pay agreement), the operator (Operating & Maintenance agreement, O&M), or the government enhance the project.

Project Finance arose in the last decades as an innovative financial instrument for RE projects. Traditionally, the majority of RE projects have usually been financed through the syndicated commercial loan market. Then, the decision maker is a bank manager who faces a multitude of criteria to decide which are the best RE projects to be financed.

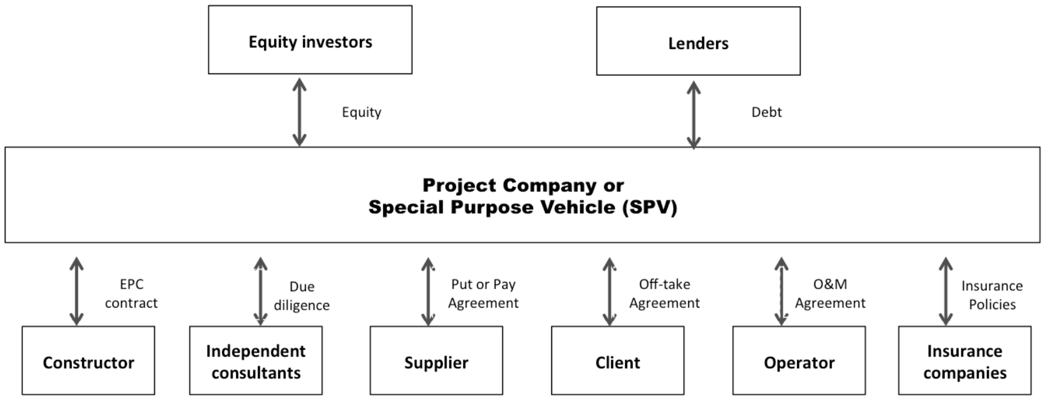

Figure 1. Basic structure for a Project Finance: participants and agreements (Source: Own elaboration)

Banks have a high-risk perception of RE projects due to their own specific characteristics such as the need of capital intensive and very long payback periods with no proven track record. For this reason, banks are hesitant to use traditional finance instruments [51].

3. MCDM in RE projects

MCDM is a branch of Operations Research models that started to emerge in the 1950s. MCDM has experienced a growing development from the 1990s until now and many subfields have emerged with a wide number of contributors. In 1992 Simon French edited the Journal of MultiCriteria Decision Analysis aimed to be the repository of choice for papers covering all aspects of MCDA/MCDM. A significant contribution to MCDM was Ballestero and Romero [11] with their book Multiple Criteria Decision Making and its Applications to Economic Problems. Relevant developments in the field of goal programming are due to Lee [46], Ignizio [34], and Romero [57]. A review of the early history of MCDM is made in [43].

According to many authors, MCDM is divided into multi-objective decision making (MODM) and multi-attribute decision making (MADM). While MODM is related to problems in which the decision space is continuous, MADM is devoted to problems with discrete decision spaces. Continuous methods seek to identify an optimal quantity, which can vary infinitely in a decision problem. Linear programming (LP), goal programming (GP) and aspiration-based models are considered continuous. Discrete methods include weighting and ranking methods as for example, Multi-attribute value theory (MAVT), multi-attribute utility theory (MAUT), Analytic Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination and Choice Expressing Reality (ELECTRE), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). A comparative analysis of MCDM methods VIKOR, TOPSIS, ELECTRE and PROMETHEE is presented in [54].

MCDM has not been an active area of research until the 1970s with important contribution from Contini and Zionts [20] and Zionts and Wallenius [73]. Saaty [58] (1977a) introduced the Analytic Hierarchy Process (AHP), a multi-criteria method that relies on pairwise comparison of criteria/assets to be evaluated from the decision maker's preferences. Keeney and Raiffa [42] established the multiattribute value theory (including utility theory) as a standard reference for decision analysis and MCDM. In the late 1970s MCDM research focused on multiple objective mathematical programming problems, especially related to linear and discrete problems [44]. In 1972, Zeleny [72] and Yu [71] organized the First International Conference on MCDM at the University of Southern California. This conference was a turning point in MCDM.

MCDM draws upon knowledge in many fields including: Mathematics, Behavioral decision theory, and Economics, Engineering and Information systems. In RE projects, MCDM has been widely used in areas such as wind farm projects, geothermal projects, and hydro-site selection. A review of multi-criteria applications in RE analysis is made in [64]. Some problems solved applying MCDM methodologies are RE planning, the assessment of environmental impact, evaluating RE strategies or life cycle strategies, among others. In Table 1 a summary of relevant contributions of MCDM in renewable energy is shown.

Table 1 Academic literature in MCDM applied to Renewable Energy Projects

Type	MCDM methodology/Application	Authors
	Multiobjective	[35]; [63][13]; [25]; [2]; [56]
MODM	Compromise Programming	[62]; [28]
	Goal Programming	[17]; [59]; [6]; [21]; [39]
	AHP	[3]; [69]; [63]; [41]; [32]; [52]; [38]; [45]
	ELECTRE	[55]; [61]; [12]; [15]; [30]
MADM	PROMETHEE	[14]; [48]; [31]
	MAUT	[50];[40]; [36]
	TOPSIS	[28]; [16]; [18]
	FUZZY AND OTHERS	[37]; [13];

Source: ISI Web of Knowledge

Recently many authors have been interested in comparing and analyzing different MCDM methods when applied to real world problems (see, for example, [19], [33], [53]). Applications to renewable energy that compare several MCDM methods can be found in [65], [65], [60].

4. MCDM Methodology: Moderate Pessimism Decision Support Model for evaluating RE projects from lenders perspective

Evaluating a Project Finance proposal for RE is a complex analysis that can be defined as a multi-criteria decision-making problem with a multidimensional space of indicators. We propose a Moderate Pessimism Decision Support Model (MPDM, [9]) to rank a set of projects in the RE sector that can be financed using the Project Finance technique. This ranking method does not require eliciting preference weights from particular preferences of the decision-maker, namely, there are no particular preferences for the selected criteria.

Before establishing the MPDM model let us begin with some previous definitions as basic postulates for moderate pessimism decision makers:

Definition 1. Moderate pessimism. A decision maker who cautiously assumes that the most favorable state when the action has been taken will not occur is named "moderately pessimism".

A critical issue in MCDM analysis is how to rank a set of alternatives from multiple criteria. Let V_{ij} be the corresponding value reached by the i^{th} alternative from the j^{th} criterion (i = 1, 2, ……m); (j = 1, 2, …n). A previous needed step is "normalization" to range the values for the j_{th} criteria between O an 1. Then, when the criterion is "the more the better" the normalized N_{ij} value is computed by:

$$N_{ij} = \frac{V_{ij} - V_{jmin}}{V_{jmax} - V_{jmin}} \tag{1}$$

If some criterion was the more the worse, then, this could be converted into the more the better N_{ij} normalized value by the following equation:

$$N_{ij} = \frac{V_{jmax} - V_{ij}}{V_{jmax} - V_{jmin}} \tag{2}$$

Definition 2. Domination. An alternative a_i is dominated by the (a_1, a_2,…a_m) convex combination of alternatives if the N_{ij} value satisfies the relationships:

$$\sum_{i=1}^{m} a_i N_{ij} \geq a_{\delta j} \text{ for all } j \tag{3}$$

Traditionally, Project Finance lenders will require that project cash flows pay the debt. Two main analyses are considered: (i) Assessing financial viability of the project; and (ii) Evaluating risks and their coverage mechanisms. While the first analysis is quantitative, in the second analysis qualitative criteria and non-financial considerations prevail.

Taking into account bank managers' preferences a set of criteria is proposed from a Delphi survey conducted in 2014. The choice of criteria should take into consideration financial but also technological, political-legal and socio-environmental perspectives of the problem. Then, we introduce these four dimensions D_i, (i = 1, 2, 3, 4) including a total of fifteen criteria (C_{ij}), (see Table 2). Dimensions and criteria are described as follows:

D1 Financial. To evaluate a project from the lender's perspective the Debt Service Coverage Ratio (DSCR) is a key financial metric to assess a project's cash flow coverage of both interest and principal repayments. For RE projects the DSCR ranges between 1.0 and 3.0,but the average in this type of projects is around 1.3. However, there are other significant financial criteria that lenders should take into account such as the net present value, the amount of debt, the guaranteed incomes and the currency risk.

D2 Political-Legal. Changes in the legal and political framework can affect the risk of the project. Host government regulations promoting environmental policies, including reduction in taxes and royalties, expropriation and nationalization, and even the outbreak of war, among others, are factors which contribute to political risk. This dimension includes:

(i) Country risk measured from Euromoney (http://www.euromoneycountryrisk.com/);

(ii) Contracts strength, in which expert consultants advise lending institutions against changes in market terms and conditions that could affect the financial rating strength of the project. This is an "more the better" criterion where 1 means the lowest score and 10 the highest one; and

(iii) Support from the administration based on the ranking carried out by RECAI (Renewable Energy Country Attractiveness Index) which indicates the level of investment in renewable energy and deployment opportunities in this field http://www.ey.com/.

This ranking shows countries with strongest commitment to renewable energies. The scale of this criterion varies from 1 to 10, being 10 the highest level and 1 the lowest.

D3 Technological. The proliferation of RE is directly related to the technical advances in processing them and the breakthroughs in terms of finding stable sources of green energy. In this dimension, source variability, fuel cost and processing complexity are assessed from the advice of technical consultants. The scale of these criteria varies from 1 to 10, being 10 the highest level and 1 the lowest.

D4 Social-Environmental. According to [1] the use of RE implies the following social and environmental benefits: (i) improved health, (ii) consumer choice, (iii) greater self-reliance, (iv) work opportunities and (v) technological advances. In this dimension we consider as basic criterion contribution to employment (measured by the number of employments generated by installed MW), social acceptance (benefits of each kind of energy, from 1 to 10), and negative impact on the environment (measured from independent consultant reports ranging from 1 to 10).

We propose the use of the variable D_{ih} as the sum of the N_{ij} values for the criteria included.

$$D_{ih} = \sum_{h=1}^{m} N_{ij} \quad i = 1,2 \ldots m \tag{4}$$

Table 2. Financial, political-legal, technological and social-environmental dimensions and criteria

D1	Financial	*D2*	Political-Legal	*D3*	Technological	*D4*	Socio-Environmental
C11	DSCR	*C21*	Country risk	*C31*	Source variability	*C41*	Contribution to the employment
C12	Net Present Value	*C22*	Contracts strenght	*C32*	Fuel cost	*C42*	Social acceptance
C13	Debt	*C23*	Support from Administration	*C33*	Processing complexity	*C43*	Negative impact in environment
C14	Guaranted incomes			*C34*	Innovation capacity		
C15	Currency risk						

Source: Own elaboration

To develop the MPDM model we follow a two-step approach. In a first step we select the non-dominated alternatives according to Definition 2. Within the second step we obtain the aggregation weights to construct the ranking of alternatives.

4.1 First step. Domination analysis

This step allows us to classify the alternatives in dominated and non-dominated by convex combinations of other alternatives [7]. To achieve this classification, the following linear programming can be performed:

$$\begin{aligned} &\min a_\delta \\ &\text{s.t.} \\ &\textstyle\sum_{i=1}^{m} a_i D_{ij} \;\geq\; a_{\delta j} \;\; for\ all\ j \\ &\sum_{i=1}^{m} a_i \;=\; 1 \end{aligned} \tag{5}$$

with the non-negativity conditions $a_i \geq 0$ for all *i*. If the result of (5) is $a_\delta = 0$, then, the δ^{th} alternative is dominated. Conversely, if the result of the minimization (5) is $a_\delta = 1$, then the δ^{th} alternative is non-dominated.

4.2 Second step: Aggregation weights and scoring

This step is undertaken to determine the w_j weights on the following principles: (a) objectivity, namely, the weights should not be colored by subjective opinions; (b) moderate pessimism, as a prudent rule of decision making under uncertainty.

Hereafter, these weights will be stated and justified. Regarding the aggregation weights the following cases can occur.

Case 1. The alternatives are ranked by an individual who is both the decision maker and the user of the ranking. For example, a chief of staff should rank job applicants from criteria such as age, skill, dress style, etc. Then, the aggregation weights are the individual preference weights for the criteria. To elicit these preference weights, outranking methods such as Analytical Hierarchy Process (AHP; [58]) are often used, although sometimes without reliability. If the number of items to be compared by pairwise comparison is rather high (around 10 or more), then the AHP results could be unreliable.

Case 2. The ranking of alternatives should be used by a community of individuals, which is a frequent case. Then, the community preferences for the criteria cannot be elicited. In fact, Arrow's Impossibility Theory or Arrow's paradox states that constructing social preferences from individual preferences is rather impossible. More precisely, no rank order voting system can convert the ranked preferences of individuals into a community-wide complete and transitive ranking, when the number of items is 3 or more [4][29]. In this case, the w_j aggregation weights are not preference weights. Methods to determine them cannot be outranking methods, but domination analysis and decision-making rules under uncertainty.

In Case 2, the criteria should be aggregated by weights objectively established, namely, individual preferences are not used at all to determine the weights. The meaning of these methods is as follows.

(i) Consistent weighting in which the weights do not change from an alternative to another. A classical paradigm is Laplace principle of insufficient reason, which assumes equal weight for every criterion (mean value).

(ii) Flexible weighting in which the weights change from an alternative to another. Lack of consistency is an ongoing concern with flexible weighting. A classical paradigm is Wald's maximin, which assumes extreme pessimism [68]. When Wald's maximin and other flexible weighting rules are used to rank from multiple criteria, there is another inconvenience that these rules do not use all the available information. See [5] as a classic research tool on the matter.

(iii) Ordered Weighted Averaging (OWA) [69] in which weights to be used in the aggregation are generated under the degree of optimism provided by a decision maker and then combined with the reordered payoffs to produce aggregated payoffs for each strategy.

(iv) Moderate Pessimism Decision Making (MPDM), also called the Principle of Moderate Pessimism [9], which combines advantages of both Laplace and Wald rules. Like Laplace's, this principle relies on consistent weights. Like Wald's, the MPDM method assumes pessimism but not extreme pessimism.

As previously explained, there are some different procedures to determine and justify the MPDM aggregation weights. In this paper we propose MPDM as a decision rule suitable for moderately pessimistic decision makers (see Definition 1). A first proposal of MPDM, more abstract than intuitive, based on the concepts of marginal fictitious alternatives (MFA) is widely developed in [9]. Hereafter, a more intuitive procedure is proposed.

Main assumption. Weights wj satisfy the following relationship:

$$\left(S_j^* - S_{j*}\right) w_1 = Q; \quad j = 1,\ldots,n \tag{6}$$

where,

$S_j^* = max\ S_{ij}$, namely, the largest S_{ij} value from the j^{th} criterion of the non-dominated set of alternatives.
S_{j*} = min S_{ij} , namely, the smallest S_{ij} value from the j^{th} criterion of the non-dominated set of alternatives.
Q = Positive constant.

This assumption has the following meaning. Equation (6) involves a comparison of maximum value S_j^* and minimum value Sj. The larger the difference $(S_j^* - S_{j*})$ the decision maker's distrust towards the j^{th} criterion, and therefore, the lower the w_j weight to be attached to the j criterion. This is because the decision maker fears that the S_j maximum is overestimated with respect to the S_j^* minimum. Accordingly, equation (6) assumes that weight w_j is inversely proportional to $(S_j^* - S_{j*})$. From equation (6), the MPDM weights are established as follows:

$$w_j = \begin{cases} \frac{1}{(S_j^* - S_{j*})} & if\ (S_j^* - S_{j*}) \neq 0 \\ 0 & if\ (V_j^* - V_{j*}) = 0 \end{cases} \tag{7}$$

To rank the alternatives, the following scores R_i are used:

$$Ri = \sum_{i=1}^{n} w_j D_{ij} \quad i = 1, 2, \dots, m \tag{8}$$

where parameters w_j are aggregation weights for the criteria.

5. Illustrative example

This application is based on twelve real RE projects that can be considered as a “simulated opportunity set". Bank managers are worried about how to rank them according to a set of financial and non-financial criteria. These RE projects were executed in Spain and Latin America using Project Finance for funding. They involved different types of RE sources such as waterpower, photovoltaic or wind power generation. The projects are shown in Table 3.

Table 3 Simulated portfolio of RE projects: Basic information

No	Project	Type	Power	Investment	Country
P1	La Jara	Wind	99	89	Spain
P2	ENCE	Biomass	50	135	Spain
P3	Alconera	Photovoltaic	15	120	Spain
P4	Solarpack	Photovoltaic	25	83	Chile
P5	Paracuru	Wind	24	260	Brazil
P6	Guanacaste	Wind	75	25	Costa Rica
P7	Malaspina	Wind	50	81	Argentina
P8	Tamaulipas	Wind	54	130	Mexico
P9	Aura Solar	Photovoltaic	300	100	Mexico
P10	Pedrado Sal	Wind	24	11	Brazil
P11	Artilleros	Wind	65	107	Uruguay
P12	Les Borges	Biomass	22	153	Spain

Source: Own elaboration

In Table 4 the corresponding N_{ij} normalized values are displayed taking into account the four dimensions D_1, D_2, D_3, D_4 and their corresponding criteria as explained in Section 4. Table 5 displays the aggregated values for the corresponding dimensions for the RE projects.

Table 4 Normalized values for the jth criteria

		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
D_1	C11	0.50	1.00	0.80	0.25	0.50	0.00	0.35	0.70	0.50	0.25	0.75	0.50
	C12	0.16	0.46	0.33	0.40	0.41	0.00	0.58	0.39	1.00	0.08	0.67	0.07
	C13	0.59	0.27	0.26	0.60	0.00	0.52	0.74	0.74	0.61	1.00	0.58	0.29
	C14	0.94	1.00	0.00	0.61	0.83	0.56	0.83	0.89	0.56	0.56	0.83	0.61
	C15	1.00	1.00	1.00	0.71	0.43	0.43	0.00	0.29	0.29	0.43	0.57	1.00
	C21	1.00	1.00	1.00	0.67	0.33	0.00	0.33	0.17	0.33	0.33	0.50	1.00
D_2	C22	0.83	0.00	0.67	0.17	0.83	1.00	0.50	0.83	0.83	0.83	0.83	0.17
	C23	1.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75
	C31	1.00	0.86	0.86	0.29	0.57	0.00	0.43	0.43	0.57	0.43	0.71	1.00
D_3	C32	1.00	1.00	1.00	1.00	0.33	0.33	0.00	0.33	0.33	0.33	0.33	1.00
	C33	1.00	0.67	0.33	0.00	1.00	0.67	0.33	0.00	1.00	0.67	0.33	0.00
	C34	0.17	0.33	0.67	1.00	0.00	0.33	0.67	0.17	0.17	0.33	0.83	1.00
	C41	0.17	0.11	0.23	0.55	0.81	0.09	0.00	0.13	1.00	0.77	0.62	0.30
D_4	C42	0.20	0.20	0.20	0.20	0.80	0.80	1.00	0.60	0.60	0.80	0.80	0.00
	C44	1.00	0.63	0.50	0.00	0.75	0.88	0.38	0.13	0.88	0.50	0.75	0.13

Table 5 Aggregated normalized values for the corresponding dimension

	D_1	D_2	D_3	D_4
P_1	3.20	2.83	3.17	1.37
P_2	3.74	1.25	2.86	0.94
P_3	2.40	2.17	2.86	0.93
P_4	2.58	1.58	2.29	0.75
P_5	2.18	1.17	1.90	2.36
P_6	1.50	1.25	1.33	1.76
P_7	2.50	1.33	1.43	1.38
P_8	3.00	1.75	0.93	0.86
P_9	2.95	1.17	2.07	2.48
P_{10}	2.31	1.42	1.76	2.07
P_{11}	3.40	1.83	2.21	2.17
P_{12}	2.48	1.92	3.00	0.43

First step. When applying model (5), we find $a_1 = a_2 = a_9 = a_{11} = 1$, thus, RE projects 1, 2, 9 and 11 are non-dominated alternatives. The results of minimization (5) for the remaining RE projects were O, thus RE projects 3, 4, 5, 6, 7, 8, 10, 12 were dominated alternatives.

Second step. With the set of non-dominated projects, P_1, P_2, P_9 and P_{11}, we obtain the dimension weights by applying Equation (6). These weights are computed as follows:

$$w_1(3.74 - 2.95) = w_2(2.83 - 1.17) = w_3(3.17 - 2.07) = w_4(2.48 - 0.94)$$

That is:

$$w_1 = 1.28, \quad w_2 = 0.60, \; w_3 = 0.91 \; and \; w_4 = 0.65.$$

Table 6. Non-dominanted alternatives and ranking weights w_1 - w_4.

	$D1$	$D2$	$D3$	$D4$
P_1	3.20	2.83	3.17	1.37
P_2	3.74	1.25	2.86	0.94
...	...	...	...	...
P_9	2.95	1.17	2.07	2.48
...	...	...	...	...
P_{11}	3.40	1.83	2.21	2.17
...	...	...	...	...
max	3.74	2.83	3.17	2.48
min	2.95	1.17	2.07	0.94
wj	1.28	0.60	0.91	0.65

In Table 6 the largest weights values correspond to financial and technological dimension (D_1 and D_3), while political-legal (D_2) and socio-environmental (D_4) dimensions are less weighted. These results are consistent with bank manager's preferences that include five and four criteria in D_1 and D_3, while for dimensions D_2 and D_4 only includes three criteria.

Finally, the MPDM scores for the RE projects are computed by applying equation (7). The numerical results appear in Table 7. According to the MPDM ranking score, the best RE project is "La Jara", a wind project located in Spain. In this project, political-legal and technological dimensions reach the highest values although the financial dimension ranks second while the social-environmental dimension has intermediate scores. The second best project corresponds to "Artilleros", another wind project built in Uruguay with rather high scores in almost all dimensions.

Table 7. RE projects ranking and MPDM score

RE Projects	MPDM score	RE Projects	MPDM score
P_1 *La Jara*	9.57	P_4 *Solarpark*	6.81
P_{11} *Artilleros*	8.87	P_{10} *Pedrado Sal*	6.76
P_2 *Ence*	8.74	P_5 *Paracuru*	6.75
P_9 *Aura*	7.97	P_8 *Tamaulipas*	6.28
P_3 *Alconera*	7.57	P_7 *Malaspina*	6.19
P_{12} *Borges*	7.32	P_6 *Guanacaste*	5.03

6. Conclusion

RE investments are viewed from academic, managerial and policy-making community as one of the most effective instruments to attain CO_2 emission reduction targets set by the Kyoto Protocol. The lack of private finance in the RE market have started to draw attention of researchers who are trying to provide better understanding of rational evaluation of RE projects from lenders perspective. Our review shows that the use of MCDM, mainly MCDA methods, to RE projects has grown significantly over the last two decades. AHP, ELECTRE, MAUT, PROMETHEE or TOPSIS are the main outranking methods with applications in the assessment of environmental impact, RE strategies or life cycle strategies among others.

For a proposal to be classified as worth funding lenders the debt service coverage ratio is the main reference and is complemented with risk coverage matrix. We address the problem by considering a set of financial and non-financial criteria grouped by dimensions. In these MCDA methods the aggregation weights are obtained from particular preferences of the decision maker. The MPDM method proposed in this paper allows ranking a set of RE projects to be funded using Project Finance from an objective perspective.

The criteria considered are grouped in four dimensions, financial, political-legal, technological and social-environmental and have been defined by a group bank managers. MPDM is able to rank a set of alternatives from an objective way. Frequently, the agents are interested in increasing the influence of certain criteria on the ranking, which is to be computed by an independent decision maker. A hint on these biases is the presence of ranges, which are very high in some criteria as compared with the ranges in other criteria. To correct the scores affected by these biases is the main contribution of MPDM. To use preference weights for this purpose is inappropriate because preferences are subjective categories.

As a contribution to practice, an application to twelve RE projects illustrate the method through numerical tables concerning basic information of the RE projects, quantitative values for all the criteria considered and ranking scores obtained from MPDM model. This application can help practitioners analyze RE projects from several dimensions.

Future research could be conducted to compare results with other ranking methods. The proposed approach requires comparisons not in terms of superiority of one method over others but in terms of appropriateness to the financial problem stated.

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