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PROJECT PORTFOLIO PRIORITIZATION STRATEGY TO EXTEND THE SERVICE LIFE OF OFFSHORE PLATFORMS – A PROMÉTHÉE V APPROACH

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ABSTRACT

This theory driven study puts forward the implementation of Multi-Criteria Decision Aid, through the PROMÉTHÉE V method, to support a decision on prioritizing a project portfolio on offshore oil and gas platforms, with aims to extend its service life. The chosen method supports, in a structured manner, the prioritization of a project portfolio which is necessary to leverage the oil production in offshore facilities, especially when they have already surpassed the plateau phase and presents production decline. Although the most relevant issues for investors are related to return on investments and the risks involved, the study suggests that other criteria are considered in specific settings. The research used data from 12 main projects of an oil and gas company and the criteria evaluations were made based on documents retrieved from the organization's database. This implementation represents a very important improvement for a well-known problem, in which the result is found based on criteria and their respective weights selected through a consensus.

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The results reinforce that any organization, with a constraint similar to the one presented in this study, may obtain relevant gains with the use of methods that clearly reflect the decision process and its criteria, assisting the decision maker's job significantly.

Keywords: Portfolio Prioritization Strategies, Offshore Platforms, PROMÉTHÉE V, Oil & Gas, MCDA

1. INTRODUCTION

Due to the constant increase on changes in the global economic scenario, the decisions on how and where to invest correctly have become more and more complex. Consequently, organizations require more strategic decisions which are not only based on their managers' experiences or intuitions that are not necessarily well-founded. In the Oil & Gas industry, one of the decision makers main challenges is to allocate resources according to the most valuable opportunities. For this reason, the Multi-Criteria Decision Aid methodology may offer the necessary support, as shown below.

According to Belton and Stewart (2002), it is important to stress that the focus of this methodology is to support or aid decision making, not to prescribe how decisions should be made or describe how decisions are made without formal support. Gomes (2007) believes decision making is a process that leads to the selection of at least one alternative among many others to solve the problem.

Some methods were developed in the last decades aiming at providing tools which are able to represent real problems, with the use of models to obtain information and comprehension. According to Clemen and Reilly (2001), decisions can be strengthened through the use of this modelling process.

The quest for scientific methods to support decision making, such as multi-criteria decision methods, meets the need to support decision-making agents in identifying objectives, consequences and potential bargains. This includes procedures that facilitate the implementation of these concepts in a logical, transparent and organized way (KEENEY, 2004).

In the oil industry, recognized by high-risk investment decisions, any process optimization will bring financial return of bigger proportions when compared to most of

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the others. When decisions are made correctly, managers and investors receive the desired returns.

In this context, the aim of this study is to offer the application of a well-structured approach which is able to aid the solution of an existing problem, seeking to prioritize projects implementation in order to execute the portfolio in a robust way. This aim is aligned with the organization strategy, since the limitation of available technical resources is real, and the projects cannot be developed concomitantly.

For this purpose, this article suggests the application of a multi-criteria method called PROMÉTHÉE (Preference Ranking Organization Method for Enrichment Evaluations), more specifically, PROMÉTHÉE V. This is a multi-criteria analytical method that leads to the identification of a complete pre-order of alternatives, given a set of restrictions and serving therefore as an alternative for the model which already exists in the company.

The portfolio, composed of twelve projects, will be divided into three smaller subportfolios with four projects each, prioritized according to the criteria established by the proposed model. Because of the reduced availability of top level oil & gas staff resources to develop the projects, which is common in many organizations during times of economic crisis. With the inclusion of this constraint, it may be possible to execute this portfolio in the course of the next three years.

2. THE DECISION THEORY FOCUS

2.1. Problem Formulation

At times, companies own a project portfolio with potential for implementation due to the need for production extension in oil production units, which is a common goal in oil fields. According to Câmara (2004), those oil production units have exceeded their production peaks. However, they come across the lack of a scientific methodology capable of supporting the appropriate prioritization.

Companies have their own methodologies that serve as assistance for scenarios where this problem can be found. Usually, there are few criteria, the weight for each criterion is given and, after that, an individual alternatives analysis is made for each selected criterion. For instance, this type of methodology reaches, as a result, a value from an alternative in each criterion with its weight, the ranking is found through

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the obtained result, from the highest to the lowest, as it can be seen in the case studied.

Alternatives are evaluated separately, according to each criterion, and there are no comparisons between them. This is one of the reasons why the methodology, usually applied in the problem, is considered overly simplistic. Another factor that contributes to this review is the selection of criteria.

The number of criteria is too small and there are different criteria associated with the same criterion in use, called "supercriterion" in this paper. Thus, when a certain alternative has an extremely positive impact over at least one of the criteria inserted in this "supercriterion", this alternative's performance is overly high. This alternative's real importance may be overlooked if the other criteria in the same "supercriterion" do not have a performance evaluation as high as the first one.

2.2. Decision making process in the Oil & Gas Industry

The history of oil exploration dates back to the 19th century, when the United States of America started its commercial exploitation. However, the beginning of the Brazilian offshore production sector was in the 70s. From then on, many oil fields went into production along Brazil's coast. However, the expansion of offshore exploration and production took place in the 90s and the discovery of pre-salt in the Tupi field was only announced in 2007, which changed Brazil's history (MBP COPPE/UFRJ, 2014).

Due to the oil industry shrinkage (oil price fall), in which the Brent value dropped from US$ 110 in June/2014 to less than US$ 30 in the beginning of 2016, it was of extreme importance that companies from this sector increased their diligence with investment decisions. Moreover, they should enhance their level of efficiency, producing more and using less resources (IEA, 2016). At the same time, oil companies are constantly confronted with investment decisions in several projects, since investments in hydrocarbons are of high risk (PARK et al., 2009; ZHANG, 2010; JAFARIZADEH, 2010; ZHANG; WANG, 2011; LIU et al., 2012).

2.3. Project Portfolio Management and Optimization

According to Barney and Hesterley (2010), the concept of project portfolio management emerged from the need to optimize resources use to ensure an efficient and effective investments return. Patanakul (2015) states that the relevance of project portfolio management is related to the decision makers' need to select, prioritize and

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control a set of initiatives, which takes into account the lack of resources as well as the the need to reach strategic goals.

Alongside the portfolio management, its optimization is also being developed. The portfolio theory suggests that this is characterized by two indicators: the portfolio's return and its expected variation. The aim of the portfolio optimization is to minimize the variation to a given return or maximize the expected return for a certain risk (MARKOWITZ, 1959).

According to Cooper et al. (1997), the project portfolio is a collection of projects and programs of a particular organization with the same strategic aims, related or not to each other, and that compete for resources use.

Cáñez and Garfias (2015) state that the elaboration of a project portfolio is essential, since individual evaluation may lead to short or long-term problems with results imbalance. It is noteworthy to identify prominently financial criteria, such as: Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period. However, this assessment has been imprecise. Brache and Bodley-Scott (2006) consider the following categories of criteria used to prioritize projects: (a) alignment with strategy; (b) sales growth; (c) cost reduction; (d) compliance with regulatory requirements, among others.

Accurate information about the projects must be available to all committee members so that the results are grounded and aligned with the organizational aims. According to Ghasemzadeh and Archer (2000), projects with multiple and conflicting aims are an additional challenge to the selection of project portfolio. Also, favorable environments for debate and support to decision making must be accessible.

Kerzner (2006) recognizes that the senior management does not have enough information to evaluate possible projects, especially when there is a probability of deviation and failure, due to the degree of uncertainty and risk.

2.4. Multi-Criteria Decision Aid

The Multi-Criteria Decision Aid (MCDA) field is, according to Gomes and Gomes (2014), a dynamic area of knowledge and research to support decision makers and negotiators, giving assistance in problem structuring, which allows the expansion of argumentation and learning and comprehension abilities.

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MCDA helps decision makers evaluate objectives and select alternatives through structured methods, in which several different qualitative and quantitative criteria, at times contradictory, are considered and evaluated (VINCKE, 1992).

For Gomes (2007), decision making is divided into 3 broad stages: problem structuring, decision analysis and synthesis; as described below:

I. Problem structuring includes: relevant information gathering, problem identification, generation of the viable alternatives set, relationship between the qualitative and quantitative objectives of decision making, objectives unfolding into criteria and the definition of each alternatives consequences for each criterion as well as the probability of these consequences' occurrence.

II. Decision analysis includes: the use of at least one existing Multi-Criteria method to select, classify, rank or describe alternatives through which decision will be made and, also, the review of obtained results. Moreover, the sensitivity analysis is carried out giving realistic modifications of variables and parameters, verifying possible changes in the decision maker's preferences.

III. At last, there is a synthesis in which the decision maker receives objective recommendations, including the proposals and how to implement them.

According to Gomes, Araya and Carignano (2004), at least four types of problems may arise during a decision analysis process, shown and defined in Table 1 below.

Table 1: Multi-Criteria Decision Aid Types of Problems

Type	**Objective**
Selection	Select the best alternative or best possible subset of satisfactory alternatives which cannot be compared to each other.
Classification	Classify each alternative in the most suitable category in a set of predefined categories.
Rank	Rank the available alternatives.
Describe	Describe alternatives, establishing their performances in selected criteria without generating prescriptions or recommendations.

Source: Adapted from Gomes (2007)

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2.5. The PROMÉTHÉE methods

The PROMÉTHÉE V method belongs to the French school's family of multi-criteria methods. It is a ranking multi-criteria method which is simpler, compared to other methods, in its conception and applications (BRANS; MARESCHAL, 1986). Its implementation is suitable for problems with restrict numbers of alternatives which need to be ranked, taking into account a group of conflicting criteria.

The method encompasses two phases: i) outranking relationship building, gathering information about alternatives and criteria; and ii) explore this relationship in order to support decision making.

The PROMÉTHÉE methods are non-compensatory methods which require intercriterion information that corresponds to the relative importance between criteria, and intracriterion information, acquired through the comparison between criteria pairs:

- Intercriterion information: is obtained through the attribution of weight to each criterion. These weights must be positive and the criterion with the biggest weight is considered the most important one.
- Intracriterion information: pairwise comparisons are made, observing the differences between the alternatives values inside each criterion. For small differences, the decision maker will have to give a weak preference for the best alternative. For big differences, a stronger preference. These preferences will take a real number between 0 and 1, which means that for each criterion $f_j(.)$, the decision maker will make use of the function in (i):

$$P_j(a,b) = P_j\,[dj(a,b)] \;\; a,b \in A, \text{ onde: } d_j(a,b) = f_j(a) - f_j(b) \;\; e \;\; 0 \leq P_j(a,b) \leq 1 \qquad \text{(i)}$$

The pair {$f_j(a)$, $P_j(a,b)$} is called generalized criterion associated with criterion $P_j(.)$. That is, it represents the degree of preference of *a* over *b* according to $d_j(a,b)$, which is the difference between the alternatives *a* and *b* performances in criterion *j*, thus, for $d_j(a,b) \geq 0$:

I. If $P_j(a,b) = 0$ there is no preference of *a* over *b* in criterion *j*.

II. If $P_j(a,b) \approx 0$ there is weak preference of *a* over *b* in criterion *j*.

III. If $P_j(a,b) \approx 1$ there is strong preference of *a* over *b* in criterion *j*.

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IV. If $P_j(a,b) = 1$ there is close preference of *a* over *b* in criterion *j*.

According to Brans et al (1986), six types of preference functions are contemplated in the PROMÉTHÉE method, as show in Table 2:

Table 2: Preference Functions

Preference Functions		Parameters
I. Usual Criterion	0 if indifferent or worst; 1 best	None
II. U-shape function	0 if d ≤ q; 1 if d > q	q
III. V-shape / Linear function	0 f indifferent or worst; d/p se vantagem < limite p; 1 se ≥ p	p
IV. Level criterion	0 if |d| ≤ q; 1/2 if q < |d| ≤ p; 1 if |d| > p	q, p
V. Linear with indifference preference	0 if |d| ≤ q; (|d|-q)/(p-q) if q < |d| ≤ p; 1 if |d| > p	q, p
VI. Gaussian criterion	0 if d < 0; $1-e^{-dxd/(2\sigma x\sigma)}$ if d > 0	σ (standard deviation)

Source: ferreira, (2013)

In the preference functions on Table 2 above, p and q parameters represent:

- q_j (indifference threshold) – the highest value for $d_j(a,b)$, under which there is a preference indifference between a*a* and *b*; and
- p_j (preference threshold) – the lowest value for $d_j(a,b)$, above which there is a close preference of *a* in relation to *b*.

Still with respect to the preference functions on Table 2:

- Type I: must be chosen in radical situations in which a minimum deviation justifies close preference.
- Types II and IV: are particularly suitable for cases of qualitative data in a discrete scale.
- Types III or V: must be selected for cases of real numbers evaluations on a continuous scale with or without indifference zone.
- Type VI: is preferred when the decision maker considers a positive degree of preference for weak deviations, this degree is increased as the deviation decreases.

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For this case study, the limitation of staff resources to execute the project portfolio, will be the restriction used.

A subset of alternatives which satisfies the restrictions, providing as many net flows as possible, will be obtained by the solution of the linear programming (0-1).

3. CASE STUDY

3.1. Methodology

Now that the problem has been defined, the scientific method and objective have also been established. Alternatives were selected based on the company's database and the criteria were defined through a process of improving existing criteria in the same organization. The model structuring was made based on the available data, qualitative and quantitative ones, which were adjusted to the proposed model.

The result was found through computer processing, using the Visual PROMETHEE software in its academic version, available free of charge to this end.

3.2. The Motivation behind choosing the PROMÉTHÉE V method

According to the literature review carried out and acknowledged by Vetschera and Almeida (2012), the PROMÉTHÉE method is one of the analysis and surpassing methods more widely used in applications involving portfolio selection issues.

The main problem in the application of surpassing methods for portfolio issues is that they require alternatives pairwise comparison - which may limit the number of alternatives considered due to the heavy mathematical work involved. Moreover, in portfolio issues, each item combination that fulfills certain constraints is a potential alternative. This leads to a high number of potential alternatives - different portfolios. Therefore, the typical methods of selecting portfolio do not explicitly generate all possible portfolios, but they try to create the ideal portfolio based on the set of available items (VETSCHERA; ALMEIDA, 2012).

The PROMÉTHÉE V method was chosen based on the literature review which has been mentioned. Besides that, it perfectly applies to the problem identified. Its applicability in the research problem analysis has the following characteristics: (i) The method is suitable for the portfolio creation; (ii) The method uses linear mathematical programming to create portfolios, integrating the PROMÉTHÉE II method and the optimization technique; (iii) The method has support computational tools, which eliminate the need to repeat manual calculations.

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3.3. Objectives and Alternatives

According to Keeney (2004), the foundation for any analysis is the objective or set of objectives, and the set of alternatives to reach this objective.

The alternatives, shown by the labels Project 1 as (P_1), Project 2 as (P_2), Project 3 as (P_3), ..., Project 12 as (P_{12}), represent the twelve modification projects established by the organization as the most important ones to be implemented in the next three years. They are ranked according to the common model, as it was mentioned before.

As an objective, the portfolio composed of these twelve projects will be divided into three smaller portfolios with four projects each, since there is a lack of staff resources to develop these projects. They seek to make the portfolio execution possible over the next three years and they were prioritized based on the established criteria and identified constraint.

3.4. Criteria Composition

Miller (1956), recommends the number of evaluated criteria to be seven, more or less two. This is due to the psychometrics studies, which demonstrate that the human brain is limited when comparing more than seven attributes at the same time. The criteria can be gathered into a "supercriterion", in three different components: Production, Compliance and Safety. In this way, each one of them is evaluated separately, constituting a set of five criteria, next to Cost and Ease.

As a result, the model is formed by the following criteria: (i) Security; (II) Compliance; (iii) Production; (iv) Cost and (v) Ease. The definitions are presented on Table 4, in the Criteria Structuring and Weights Attribution section.

3.5. Data Collection

The research is limited to the 12 main projects identified in an oil & gas company. The projects information and their evaluation in the studied criteria were gathered based on the documents from the organization's database. The data obtained can be seen on Table 3:

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Table 3: Original projects, their criteria and weights

DATA COLLECTION					
PROJECTS		Criterion 1	Criterion 2	Criterion 3	TOTAL
		Weight 5	Weight 2	Weight 3	
ID	Area of application	Security / Compliance / Production	Cost	Ease	
P_1	Technical Safety	10	10	8	94
P_2	Electrical	8	10	10	90
P_3	Process Safety	10	6	7	83
P_4	Technical Safety	10	5	7	81
P_5	Process Safety	8	8	8	80
P_6	Utilities	10	4	7	79
P_7	Electrical	8	7	8	78
P_8	Electrical	8	7	8	78
P_9	Naval	7	7	8	73
P_{10}	Electrical	6	9	8	72
P_{11}	Corrosion Management	7	6	8	71
P_{12}	Utilities	8	5	7	71

3.6. Data Processing

The data from Table 3 was revised and processed alongside the group responsible for the method structuring which already exists in the organization, across meetings with experts from the areas of Operations, Integrity assurance of Offshore installations and Offshore Modification Projects Management.

This work was necessary to organize the existing data in order to adjust them into the established criteria and weights and, also, for them to be processed by the PROMÉTHÉE method.

The multidisciplinary team, conducted by the Decision Analyst, was consulted for the criteria structuring with due preference, types, weights and preference and indifference thresholds functions. The evaluation of these parameters was carried out based on the company's Decision Analyst and Decision Maker's knowledge. The other group components were: a modification projects manager, the platforms integrity manager, an operations engineer and a project cost control coordinator.

3.7. Criteria Structuring and Weights Attribution

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Following the criteria adopted by the organization and adapting them as described above, the criteria structuring and their weights for the method's implementation are the following:

Safety: It is a type I (Usual) and maximization criterion, in which the highest value has preference over the lowest one. It will be evaluated according to a qualitative scale of impact of five elements (1 to 5):

- 5 for projects with very high positive impact over the degree of safety;
- 4 for projects with high impact;
- 3 for projects with moderate positive impact;
- 2 for projects with low positive impact;
- 1 for projects without any impact over the degree of safety.

Since safety is a basic value for the industry at hand, the weight attributed to the criterion will be 25.

Compliance: It is a type I (Usual) and maximization criterion. It will be evaluated in the simplest qualitative way, with a binary scale. "Yes" for projects that meet some compliance requirements, and "No" for the ones that do not have compliance to any requirements.

To be in compliance with rules and regulations is mandatory, the weight attributed to the criterion will also be 25. It is important to say that requirements, which fit into this criterion, usually have a deadline for implementation and the Company will not fail to fulfill any deadlines because of portfolio prioritization matters. The method's implementation seeks to provide inputs on when the project will be executed, since it respects any limits imposed by the specific requirement.

Product: It is a type III (Linear Preference – V-Shape) and maximization criterion. It will be evaluated according to a quantitative Likert scale of five elements (1 to 5):

- 5 for projects with potential for increased production over 2 kBOE/day;
- 4 for projects with potential for increased production between 1 and 2 kBOE/day;
- 3 for projects with potential for increased production between 0.5 and 1 kBOE/day;

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- 2 for projects with potential for increased production between 0.1 and 0.5 kBOE/day;
- 1 for projects with potential for increased production between 0 and 0.1 kBOE/day.

Since this criterion is connected with the revenue-generating activity, its weight will be 22.5.

Cost: It is a type V (Linear Preference with indifference area) and minimization criterion. It will be based on a monetary scale, using American dollars as a reference. The values correspond to the total cost foreseen for the project's implementation.

Projects that belong to the portfolio at hand, require considerable low investments for the industry, therefore, the weight of this criterion will be 12.5.

Ease: It is a type IV (Levels) and maximization criterion. It will be evaluated according to a qualitative Likert scale of five degrees (1 to 5):

- 5 for projects with very low degree of complexity;
- 4 for projects with low degree of complexity;
- 3 for projects with moderate degree of complexity;
- 2 for projects with high degree of complexity;
- 1 for projects with very high degree of complexity.

Although this criterion is extremely important, its weight will be the least relevant one comparing to the three first ones, reflecting its real importance to the company. Thus, its weight will be 15, making the sum of all criteria weights be 100.

With the criteria now defined and their types established according to preference functions and attributed weights, Table 4 is given:

Table 4: Criteria Definitions, their types and weights

Criterion	Definition	Typo	Min/Max	Weigh t
Safety	It measures the project's positive impact on the installations safety.	I	Maximize	25
Compliance	It measures whether the project has or not the aim to meet an existing requirement, internal or external to the organisation.	I	Maximize	25

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Production	It measures the potential increase of the installation's production efficiency with the project's implementation.	III	Maximize	22.5
Cost	It measures the cost of investment needed for the project's implementation.	V	Minimize	12.5
Ease	It measures the degree of easiness for the project's implementation.	IV	Maximize	15

Table **5** was established as a result of this work of adequacy of data collected and structured by the multidisciplinary team.

Table 5: Parameters input on the PROMÉTHÉE Application

THE PROMÉTHÉE V METHOD APPLICATION										
	C1		**C2**		**C3**		**C4**		**C5**	
	Safety		**Compliance**		**Production**		**Cost**		**Ease**	
Preference	**Maximize**		**Maximize**		**Maximize**		**Minimize**		**Maximize**	
Type	**I**		**I**		**III**		**V**		**IV**	
Thresholds	**P: -**	**Q: -**	**P: -**	**Q: -**	**P: 1**	**Q: -**	**P: 0.5**	**Q: 0.25**	**P: 2**	**Q: 1**
Weights / Projects	**25**		**25**		**22.5**		**12.5**		**15**	
P_1	5		No		1		0.8		4	
P_2	3		No		1		0.6		5	
P_3	4		Yes		1		2.3		3	
P_4	4		Yes		1		2.2		3	
P_5	4		Yes		2		1.2		4	
P_6	2		No		4		3		3	
P_7	3		Yes		1		1.7		4	
P_8	3		No		2		1.1		4	
P_9	1		No		3		1.3		4	
P_{10}	3		Yes		1		1		4	
P_{11}	3		No		1		2.3		4	
P_{12}	1		No		4		1.9		3	

3.8. The PROMÉTHÉE Method Computer Processing

The Visual PROMÉTHÉE software was used, in its academic version and free of charge, to apply this method. The data for Table **5** were inserted into the software and result is shown below:

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Scenario1	Safety	Compliance	Production	Cost	Ease
Unit	impact	unit	5-point	unit	5-point
Cluster/Group	◆	◆	◆	◆	◆
Preferences					
Min/Max	max	max	max	min	max
Weight	25.00	25.00	22.50	12.50	15.00
Preference Fn.	Usual	Usual	V-shape	Linear	Level
Thresholds	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	n/a	n/a	n/a	$ 0.25	1.00
- P: Preference	n/a	n/a	1	$ 0.50	2.00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a
Statistics					
Evaluations					
Project 1	Very high	No	1	$ 0.80	Easy
Project 2	Moderate	No	1	$ 0.60	Very easy
Project 3	High	Yes	1	$ 2.30	Moderate
Project 4	High	Yes	1	$ 2.20	Moderate
Project 5	High	Yes	2	$ 1.20	Easy
Project 6	Low	No	4	$ 3.00	Moderate
Project 7	Moderate	Yes	1	$ 1.70	Easy
Project 8	Moderate	No	2	$ 1.10	Easy
Project 9	Very low	No	3	$ 1.30	Easy
Project 10	Moderate	Yes	1	$ 1.00	Easy
Project 11	Moderate	No	1	$ 2.30	Easy
Project 12	Very low	No	4	$ 1.90	Moderate

Picture 1: Data inserted in the *Visual PROMÉTHÉE software*

After data entry, the model was executed and the following results of outranking positive (ϕ^+ or Phi+), negative (ϕ^- or Phi-) and net flows (ϕ or Phi) were obtained. Table 6 presents this result ranked by PROMÉTHÉE II.

Table 6: PROMÉTHÉE II Ranking

Alternatives	ϕ^+	ϕ^-	ϕ
Project 5	0.5523	0.1023	0.4500
Project 4	0.3523	0.2205	0.1318
Project 3	0.3523	0.2250	0.1273
Project 1	0.3386	0.2159	0.1227
Project 10	0.2977	0.2000	0.0977
Project 7	0.2727	0.2568	0.0159
Project 8	0.2795	0.2795	0.0000
Project 2	0.2318	0.3068	-0.0750
Project 9	0.2477	0.4068	-0.1591
Project 12	0.2318	0.4227	-0.1909
Project 6	0.2500	0.4568	-0.2068
Project 11	0.0795	0.3932	-0.3136

Picture 2 presents the contributions of each criterion to the alternative in the net flow result. Criteria with positive impact on the alternative's net flow in the ranking

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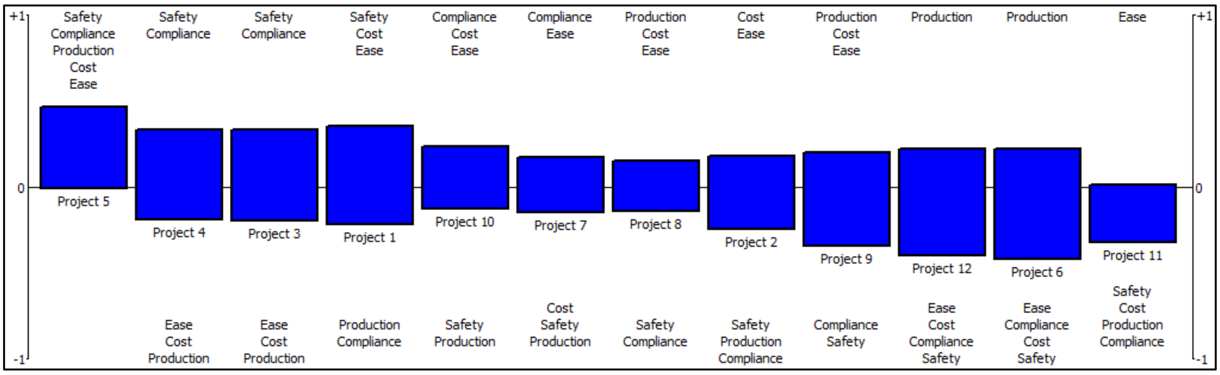
appear in the chart's upper area and criteria with negative impact appear in the chart's bottom area.



Picture 2: Disintegrated vision of ϕ - PROMÉTHÉE II

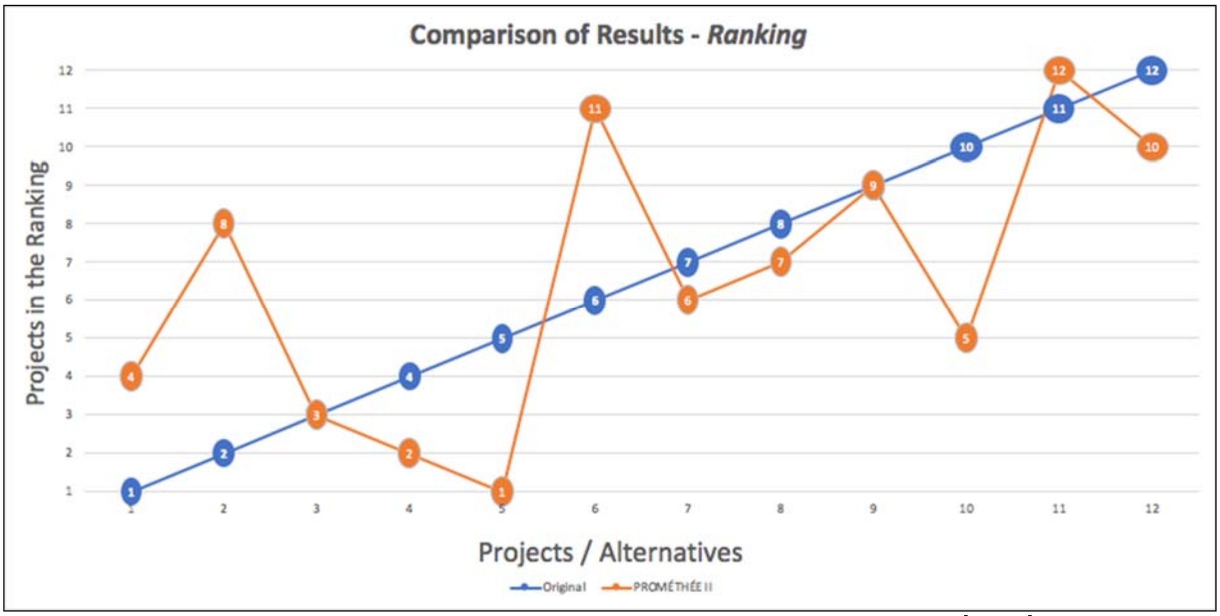
With the ranking now established, it is easy to compare the obtained results from the model's data collection, which already exists in the organization, with the PROMÉTHÉE II's ranking. This comparison is expressed below:

Ranking of the organization's original method:

$P_1 – P_2 – P_3 – P_4 – P_5 – P_6 – P_7 – P_8 – P_9 – P_{10} – P_{11} – P_{12}$

Ranking of the PROMÉTHÉE II method:

$P_5 – P_4 – P_3 – P_1 – P_{10} – P_7 – P_8 – P_2 – P_9 – P_{12} – P_6 – P_{11}$



Picture 3: Results comparison – Original model and PROMÉTHÉE II

The ranking from PROMÉTHÉE II was completely different from the original model. Among the six first projects ranked in the organization's model, only four – P_1, P_3, P_4 and P_5 - remained in the first six positions of PROMÉTHÉE II ranking. Even so,

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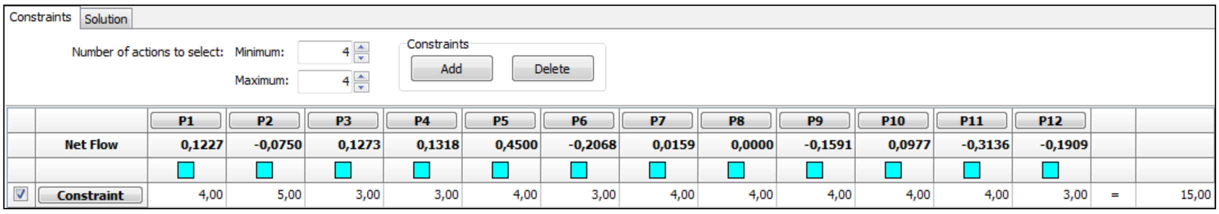
three of them appeared in positions different from the original ones, with the exception of Project 3, which remained in the third position.

3.9. Inclusion of Constraint – PROMÉTHÉE V

The portfolio composed of twelve projects needs to be divided into three subportfolios and aligned with the organization's strategy to plan the execution of this portfolio in the next three years. It is also important to take into account the lack of staff resources to develop these projects, which is a common fact for these companies, especially during economic crisis.

These three subportfolios are limited by the sum of scores in the "Ease" criterion of each one of the projects. When this sum is 45 on Table 5, the restriction will be established in a way that each subportfolio is composed of four projects and the sum for each of the three portfolios is 15, the aim is to balance the complexity between them.

With the constraint is imposed, the software's setting is presented as below:


Constraints Solution
Number of actions to select: Minimum: 4 Maximum: 4
Constraints Add Delete

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12		
	Net Flow	0,1227	-0,0750	0,1273	0,1318	0,4500	-0,2068	0,0159	0,0000	-0,1591	0,0977	-0,3136	-0,1909		
☑	Constraint	4,00	5,00	3,00	3,00	4,00	3,00	4,00	4,00	4,00	4,00	4,00	3,00	=	15,00

Picture 4: Inclusion of the first constraint into the model – First subportfolio

With the constraint, the first subportfolio is composed by: Project 5, Project 4, Project 1 and Project 10. It is possible to see that Project 3, which was in the third position of the complete ranking, was not selected to integrate the first subportfolio. This is due to the fact that Project 3 has a low evaluation in its ease, the constraint allowed the inclusion of alternatives with higher values to form the group of projects. The results are presented in Picture 5:

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Actions		Net Flow	Optimal	Compare
		Total:	0,8023	0,8023
Project 1		0,1227	yes	yes
Project 2		-0,0750	no	no
Project 3		0,1273	no	no
Project 4		0,1318	yes	yes
Project 5		0,4500	yes	yes
Project 6		-0,2068	no	no
Project 7		0,0159	no	no
Project 8		0,0000	no	no
Project 9		-0,1591	no	no
Project 10		0,0977	yes	yes
Project 11		-0,3136	no	no
Project 12		-0,1909	no	no

Constraints	Optimal			Compare		
	LHS		RHS	LHS		RHS
Minimum	4,00	>=	4,00	4,00	>=	4,00
Maximum	4,00	<=	4,00	4,00	<=	4,00
Constraint	15,00	=	15,00	15,00	=	15,00

Picture 5: The Result of the first project subportfolio with the inclusion of constraint

In order to establish a second subportfolio, a second constraint was added to the software in the same way the first one was. However, the projects selected to the first subportfolio were deactivated. The configuration is presented in Picture 6:

Constraints | Solution

Number of actions to select: Minimum: 4 Maximum: 4

Constraints: Add | Delete

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12		
	Net Flow	0,1227	-0,0750	0,1273	0,1318	0,4500	-0,2068	0,0159	0,0000	-0,1591	0,0977	-0,3136	-0,1909		
☐	Constraint	4,00	5,00	3,00	3,00	4,00	3,00	4,00	4,00	4,00	4,00	4,00	3,00	=	15,00
☑	Constraint 2	0,00	5,00	3,00	0,00	0,00	3,00	4,00	4,00	4,00	0,00	4,00	3,00	=	15,00

Picture 6: Inclusion of constraint into the model – Second subportfolio

The modelling was executed and the second subportfolio was composed by: Project 3, Project 7, Project 8 and Project 9.

This time, Project 2, which was in the eighth place of the complete ranking, was not select for the second subportfolio. This is due to the fact that Project 2 has the best evaluation in the criterion ease, the constraint hindered its inclusion on the second group of projects. The results are displayed in Picture 7:

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Actions		Net Flow	Optimal	Compare
		Total:	-0,0159	-0,0159
Project 1		n/a	n/a	n/a
Project 2		-0,0750	no	no
Project 3		0,1273	yes	yes
Project 4		n/a	n/a	n/a
Project 5		n/a	n/a	n/a
Project 6		-0,2068	no	no
Project 7		0,0159	yes	yes
Project 8		0,0000	yes	yes
Project 9		-0,1591	yes	yes
Project 10		n/a	n/a	n/a
Project 11		-0,3136	no	no
Project 12		-0,1909	no	no

Constraints	Optimal			Compare		
	LHS		RHS	LHS		RHS
Minimum	4,00	>=	4,00	4,00	>=	4,00
Maximum	4,00	<=	4,00	4,00	<=	4,00
Constraint	n/a	=	15,00	n/a	=	15,00
Constraint 2	15,00	=	15,00	15,00	=	15,00

Picture 7: The Result of the second project subportfolio with the inclusion of constraints

To define the third and last subportfolio, it was not necessary to include the constraint again, since the four remaining projects form the group. Following the PROMÉTHÉE II ranking, the third subportfolio is composed of Project 2, Project 12, Project 6 and Project 11, ranked according to their outranking performances.

As expected, the result obtained by the PROMÉTHÉE II ranking was changed in order to meet the constraint needed for the PROMÉTHÉE V application.

In this way, the final results of the three subportfolios, with the alternatives ranked according to the prioritization made by PROMÉTHÉE V, were:

- Subportfolio 1: $P_5 – P_4 – P_1 – P_{10}$
- Subportfolio 2: $P_3 – P_7 – P_8 – P_9$
- Subportfolio 3: $P_2 – P_{12} – P_6 – P_{11}$
- Complete Portfolio: $P_5 – P_4 – P_1 – P_{10} – P_3 – P_7 – P_8 – P_9 – P_2 – P_{12} – P_6 – P_{11}$

As a matter of reference for comparison, this is the result of the PROMÉTHÉE II ranking:

- $P_5 – P_4 – P_3 – P_1 – P_{10} – P_7 – P_8 – P_2 – P_9 – P_{12} – P_6 – P_{11}$

By comparing both results, it is possible to see that projects P3, P9 and P2 changed positions in the ranking in order to respect the subportfolios prioritization, given their easiness to be executed.

3.10. The PROMÉTHÉE II Sensitivity Analysis

The aim of the following sensitivity analysis was to evaluate how sensitive the proposed model is, when some of its parameters are altered.

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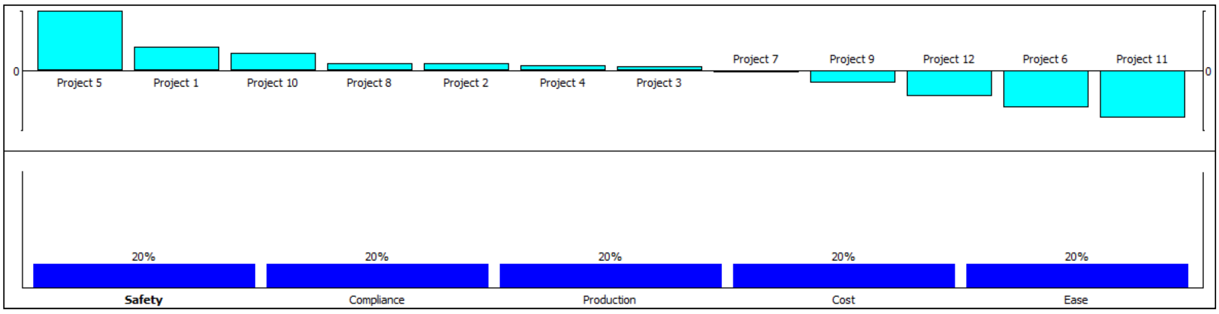
The purpose of this stage is to distribute the weights equally, 20 for each of the five criteria. This simulation intends to demonstrate how the result of the model can be affected when weights attribution is not given the appropriate importance.

After levelling, Table 7 presents the ranking provided by the software:

Table 7: Ranking for criteria with equal weights, provided by PROMÉTHÉE II

Alternatives	ϕ^+	ϕ^-	ϕ
Project 5	0.5091	0.1018	0.4073
Project 1	0.3418	0.1818	0.1600
Project 10	0.2945	0.1745	0.1200
Project 8	0.2909	0.2400	0.0509
Project 2	0.3018	0.2545	0.0473
Project 4	0.2909	0.2582	0.0327
Project 3	0.2909	0.2655	0.0254
Project 7	0.2545	0.2655	-0.0110
Project 9	0.2655	0.3491	-0.0836
Project 12	0.2255	0.4000	-0.1745
Project 6	0.2182	0.4727	-0.2545
Project 11	0.0727	0.3927	-0.3200

The software also provides the ranking output in a visual way, where the result of net flow can be observed in the chart, Picture 8.



Picture 8: Chart ranking of alternatives with equal weights provided by PROMÉTHÉE II

There were considerable changes of projects position when compared to the model proposed by the study. Although Projects 5 and 11 are still on the first and last positions, respectively, all projects between the second and eighth changed their positions in the ranking with equivalent weights. These changes of position are presented below:

Pre-ranking of the PROMÉTHÉE II method – proposed base model:

$P_5 – P_4 – P_3 – P_1 – P_{10} – P_7 – P_8 – P_2 – P_9 – P_{12} – P_6 – P_{11}$

Pre-ranking of the PROMÉTHÉE II method – weights levelling between criteria:

$P_5 – P_1 – P_{10} – P_8 – P_2 – P_4 – P_3 – P_7 – P_9 – P_{12} – P_6 – P_{11}$

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Besides demonstrating that the choice of weights is fundamental to the adequate ranking result, it is also possible to conclude that Projects 9, 12, 6 and 11, placed in last positions of the ranking, are in fact the alternatives with worst evaluations according to the selected criteria, since this subportfolio kept the same elements.

3.11. The PROMÉTHÉE V Sensitivity Analysis for weights levelling

The same constraint applied in the model was established for the weights levelling between the five criteria and was inserted into the software, Picture 9.

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12		
	Net Flow	0,1600	0,0473	0,0255	0,0327	0,4073	-0,2545	-0,0109	0,0509	-0,0836	0,1200	-0,3200	-0,1745		
☑	Constraint	4,00	5,00	3,00	3,00	4,00	3,00	4,00	4,00	4,00	4,00	4,00	3,00	=	15,00

Picture 9: Inclusion of constraint for the PROMETHÉE V sensitivity analysis with equal weights to prioritize the first subportfolio

Based on the prioritization, the first subportfolio was composed by: Project 5, Project 1, Project 10 and Project 4. The results produced by the software are shown in Picture 10.

Actions		Net Flow	Optimal	Compare
		Total:	0,7200	0,7200
Project 1		0,1600	yes	yes
Project 2		0,0473	no	no
Project 3		0,0255	no	no
Project 4		0,0327	yes	yes
Project 5		0,4073	yes	yes
Project 6		-0,2545	no	no
Project 7		-0,0109	no	no
Project 8		0,0509	no	no
Project 9		-0,0836	no	no
Project 10		0,1200	yes	yes
Project 11		-0,3200	no	no
Project 12		-0,1745	no	no

Constraints	Optimal			Compare		
	LHS		RHS	LHS		RHS
Minimum	4,00	>=	4,00	4,00	>=	4,00
Maximum	4,00	<=	4,00	4,00	<=	4,00
Constraint	15,00	=	15,00	15,00	=	15,00

Picture 10: Result of the first subportfolio - PROMÉTHÉE V Sensitivity Analysis

The first prioritized subportfolio presented the same result of the constraint in the base model. However, projects changed their positions in the ranking, as shown by PROMÉTHÉE II new ranking. This result did not alter the creation of the first subportfolio, but it shows that constraint may alter formulation in case the weights change the ranking established by the PROMÉTHÉE II method significantly.

In order to prioritize the second subportfolio, the constraint was inserted into the software again.

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Modelling was executed and the second selected subportfolio was composed by: Project 8, Project 3, Project 7 and Project 9. Just as the first subportfolio, the second one did not alter in terms of alternatives, although the PROMÉTHÉE II ranking has been altered significantly. The four prioritized projects for the second subportfolio are shown in Picture 11.

Actions		Net Flow	Optimal	Compare
		Total:	-0,0182	-0,0182
Project 1		n/a	n/a	n/a
Project 2		0,0473	no	no
Project 3		0,0255	yes	yes
Project 4		n/a	n/a	n/a
Project 5		n/a	n/a	n/a
Project 6		-0,2545	no	no
Project 7		-0,0109	yes	yes
Project 8		0,0509	yes	yes
Project 9		-0,0836	yes	yes
Project 10		n/a	n/a	n/a
Project 11		-0,3200	no	no
Project 12		-0,1745	no	no

Constraints	Optimal			Compare		
	LHS		RHS	LHS		RHS
Minimum	4,00	>=	4,00	4,00	>=	4,00
Maximum	4,00	<=	4,00	4,00	<=	4,00
Constraint	n/a	=	15,00	n/a	=	15,00
Constraint 2	15,00	=	15,00	15,00	=	15,00

Picture 11: Results of the second subportfolio - PROMÉTHÉE V Sensitivity Analysis

It was not necessary to insert the constraint again into the software in order to define the third and last subportfolio, since the four remaining projects integrate the last subportfolio. According to the ranking established by PROMÉTHÉE II for sensitivity analysis, the third subportfolio was composed by: Project 2, Project 6, Project 12 and Project 11. Therefore, the three resulting subportfolios were:

- Subportfolio 1: $P_5 – P_1 – P_{10} – P_4$
- Subportfolio 2: $P_8 – P_3 – P_7 – P_9$
- Subportfolio 3: $P_2 – P_{12} – P_6 – P_{11}$
- Complete Portfolio: $P_5 – P_1 – P_{10} – P_4 – P_8 – P_3 – P_7 – P_9 – P_2 – P_{12} – P_6 – P_{11}$

Based on the final result of sensitivity analysis with weights levelling between criteria, the imposed constraint did not alter the final result. However, from this analysis it is possible to conclude that the PROMÉTHÉE II ranking is of utmost importance for the final stage of prioritization.

4. CONCLUSIONS

The proposal described in this study puts forward a relevant theme. Through the use of a structured methodology, which is scientifically established, it is possible to improve an existing process of the company. It can be applied in a relatively simple

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manner, if the organization is ambitious enough to optimize its way of work with the use of the methodology presented.

The aim of portfolio optimization, described by Brache and Bodley-Scott (2006), was achieved in the proposed model. The authors state that the criteria used to prioritize projects of a certain portfolio should be aligned with the organization's strategy. The result sought by the organization can be found in a structured manner.

This work can be an important step towards the use of the MCDA methodology in oil companies, in which the size of their project portfolio struggles with available resources. The proposed method has the necessary elements to add to the projects ranking in a portfolio, being able to adequate them to the existing constraint, considering lack of professionals to develop these projects.

The sensitivity analysis was made, and the impacts were basically on the portfolio ranking itself. Therefore, the prioritization of subportfolios, which resulted from the inclusion of constraint, did not change, keeping the result stable when compared to the base model. One of the possible evaluations of the result is that the constraint imposed a certain limitation. Since the number of projects of great difficulty is similar to the amount of proposed subportfolios, the model kept the level of difficulty distributed among subportfolios, which allowed the result the company wanted to be reached.

With that, it is understood that organizations with a constraint similar to the one proposed may have relevant gains with the use of scientific methods which clearly mirror the decision process and its criteria and assist the decision maker. As this study suggests, this is possible as long as the model structuring is made in a transparent way, representing its preferences clearly.

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