PRIORITIZING CRITERIA TO EVALUATE PROJECT SUCCESS: MODELING WITH THE ANALYTIC HIERARCHY PROCESS (AHP)

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ABSTRACT

Despite numerous attempts to systematize the evaluation of project success, the topic remains unaddressed, mainly because of the lack of appropriate models for dealing with the subjectivity associated with evaluation. This paper aims to contribute to this discussion by proposing a model for determining the relative importance of the criteria based on a multi-criteria technique (AHP). A core feature of the AHP is determining the relative weights of the criteria, considering the subjectivity associated with the problem. The proposed model was applied to a set of data collected through structured interviews from a sample of 54 respondents consisting of managers and project professionals in a given organization. The criteria with the highest priorities were 'learning opportunities' (20.4%), 'scope' (15.8%) and 'innovation' (14.1%). Unexpectedly, the criteria ‘cost’, ‘schedule’, and ‘scope’, although widely used in evaluating success, did not rank as most important. This proposed prioritization can be useful to top management when making decisions about the application of resources that contribute to the success of the projects in the organization, as well as to guide project managers as they decide what actions are necessary to address the most relevant aspects in the context of the organization.

Keywords: project performance; project success criteria; project success; multicriteria decision analysis (MCDA); Analytic Hierarchy Process (AHP)

1. Introduction

One of the problems faced by organizational leaders is how to evaluate the success of their projects. It is necessary for leaders to be able to determine the relative importance of the factors or criteria that influence the success of projects. Despite existing efforts to address this problem, this question remains, mainly due to the lack of adequate models to deal with the subjectivity present in evaluation.

There are several published works that discuss establishing criteria weights in the context of project evaluation including da Silva et al. (2021), Roy, Das, Kar and Pamučar (2019), Šenitková, Burdová and Vilčeková (2010), Yi, Li and Zhang (2019) and Zagonari (2016). However, despite the great advances achieved in these studies, most of them do not use modeling based on trade-offs for the treatment of the data collected regarding the importance of criteria. It also appears that these works are not based on specific techniques that recognize and address subjectivity, despite the existence of multicriteria decision making (MCDM) which is specifically developed for decisions in subjective environments. According to Keeney and Raiffa (1993) and Saaty (1980), eliciting weights for the importance of criteria involves the use of perception discovery methods based on trade-off administration.

This work fills the gap in the literature by proposing and applying the Analytic Hierarchy Process (AHP), which is a MCDM method supported by a trade-off algorithm to obtain the relative importance of the weights of the project evaluation criteria. This is based on a multicriteria technique that has at its core the attribution of relative weights of criteria considering the subjectivity inherent to the problem (Rocha, Barros, Silva & Costa, 2016).

In general, this study answers the following research questions:

- What are the criteria for evaluating success in projects reported in the scientific literature?
- What is the relative importance attributed to each criterion found in the literature from the perspective of project management specialists, executives and others involved in the projects?

In order to answer these questions, some procedures were performed, and the methods applied are described in section 2. In section 3, we present the application of the AHP approach. In section 4, we discuss the results, the practical applications, and limitations of the study, and finally, section 5 presents the conclusion with suggestions of further studies.

2. Methods

This study was organized in the following stages: literature review, (project success criteria), construction of the data collection instrument, data collection, construction of criteria, hierarchy of criteria, pairwise judgment of value from the data obtained in the survey, evaluation of the consistency of the pairwise evaluations, and prioritization analysis (from eigenvectors). These stages are presented in Figure 1.

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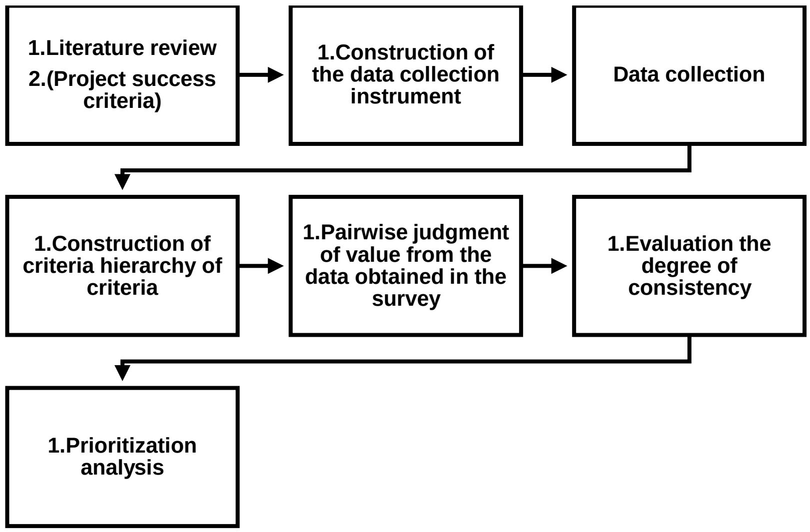

Figure 1 Procedure flow

2.1 Literature review

To further understand project evaluation criteria, bibliographic research was carried out through a literature review of papers published in journals indexed in Scopus or in Web of Sciences (WOS). According to Rodriguez, Costa and Carmo (2013), these selection criteria avoid the use of non-peer reviewed articles and reduce the probability of taking into account the so called “gray literature” (Rothstein & Hopewell, 2009) or even predatory sources.

2.2 Construction of the data collection instrument

To understand the degree of application of each of the criteria identified in the literature, respondents were asked to choose the alternative that would best represent their opinion regarding the use of these criteria in the organization according to the following scale:

(1) Strongly disagree;
(2) Disagree;
(3) Neither agree / disagree;
(4) Agree;
(5) Strongly agree.

2.3 Data collection

Based on the theoretical findings, the survey was carried out by direct questioning of those involved in project management in the organization by asking about their experience in the organization related to project performance. The questionnaires contained objective questions about their experience with projects in the organization, specifically about the criteria for evaluating their performance in the projects.

2.4 Prioritizing the criteria

The AHP was applied to assign weights to each criterion using the eigenvector. As reported in Costa and Correa (2010) and Rocha, Barros, Silva and Costa (2016), the

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choice of this method is justified when the problem of weight assignment is a tradeoff problem. The AHP algorithm is adequate to deal with this type of problem, where the preference for one criterion leads to the substitution of another with lesser preference.

As reported in Saaty (1980), when building a model based on AHP, the following steps are applied:

- Build the hierarchy of criteria
- Perform the pairwise comparison of criteria according to their relevance regarding the goal
- Run the AHP prioritization algorithm
- Evaluate the consistency of the pairwise evaluations
- Perform a sensitivity analysis

3. An AHP approach to evaluate the criteria prioritization

This section shows the outcome of the steps described in the methods section. For better understanding, it has been organized according to the same structure as the methods section.

3.1 Criteria definitions

In this section, the criteria collected during the literature review and data collection procedure are presented.

3.1.1 Criteria collected from the literature review

The theme "project success evaluation criteria" was searched in Scopus and Web of Science databases from April 10, 2018 to April 16, 2018. Table 1 presents the criteria, a short description of each criterion and references where each criterion was cited.

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Table 1
Criteria for evaluating success in projects

Criterion	Short description	References
▪ Schedule	▪ Carried out within the initially established period	▪ Pinto and Slevin (1988), Shenhar et al. (1997), De Wit (1988), Baccarini (1999), Judge and Müller (2005), Abdulah et al. (2010), Serrador and Turner (2015), Albert et al. (2017), Koops et al. (2017), Pollack et al. (2018), Redda and Turner (2018)
▪ Cost	▪ Does not exceed the established budget limits	▪ Pinto and Slevin (1988), Shenhar et al. (1997), De Wit (1988), Baccarini (1999), Judge and Müller (2005), Andersen et al. (2006), Abdulah et al. (2010), Serrador and Turner (2015), Albert et al. (2017), Koops et al. (2017), Pollack et al. (2018), Redda and Turner (2018)
▪ Scope	▪ Carried out in the scope, technical performance and expected quality, according to prescribed requirements and unstated expectations.	▪ Pinto and Slevin (1988), Shenhar et al. (1997), De Wit (1988), Atkinson (1999), Baccarini (1999), Judge and Müller (2005), Abdulah et al. (2010), Serrador and Turner (2015), Albert et al. (2017), Koops et al. (2017), Pollack et al. (2018), Redda and Turner (2018)
▪ Efficiency	▪ Resources rationally applied	▪ De Wit (1988), Atkinson (1999), Baccarini (1999), Judge and Müller (2005), Andersen et al. (2006), Serrador and Turner (2015)
▪ Mission/purpose	▪ The output of the project fulfilled the desired purpose that motivated the realization of the project	▪ Pinto and Slevin (1988), Shenhar et al. (1997), Atkinson (1999), Baccarini (1999), Judge and Müller (2005), Andersen et al. (2006), Serrador and Turner (2015), Montes-Guerra et al. (2015)
▪ Organizational benefits	▪ Contributes strategically to the organization	▪ De Wit (1988), Atkinson (1999), Baccarini (1999), Judge and Müller (2005), Andersen et al. (2006), Serrador and Turner (2015), Redda and Turner (2018)
▪ Preparing for the future	▪ Creates conditions for continuous organizational development.	▪ Shenhar et al. (1997), Serrador and Turner (2015), Redda and Turner (2018)
▪ Stakeholders satisfaction	▪ Meets stakeholders expectations, including	▪ Pinto and Slevin (1988), Shenhar et al. (1997), De Wit (1988), Atkinson

Criterion	Short description	References
	sponsor, end-user and project team, suppliers, etc.	(1999), Baccarini (1999), Judge and Müller (2005), Andersen et al. (2006), Serrador and Turner (2015), Albert et al. (2017), Koops et al. (2017)
▪ Political and social aspects	▪ Meets motivating political and social expectations	▪ Montes-Guerra et al. (2015), Koops et al. (2017), Redda and Turner (2018)
▪ Legality and compliance	▪ Carried out respecting governance rules, observing legality and compliance requirements.	▪ Montes-Guerra et al. (2015), Koops et al. (2017), Redda and Turner (2018)
▪ Safety	▪ Carried out safely and offers security to the end user	▪ Koops et al. (2017), Acheamfour et al. (2019)
▪ Sustainability	▪ Positively impacts the environment, society and finances.	▪ Koops et al. (2017), Acheamfour et al. (2019), Mansell and Philbin (2020)

3.1.2 Data collection

All criteria identified in the bibliometric study were included in the form used by the researcher for direct contact with the participants of the survey. Thus, the participant who was interviewed was asked to give information about the gradation used by the studied organization to evaluate projects using the scale (1) Strongly disagree; (2) Disagree; (3) Neither agree / disagree; (4) Agree and (5) Strongly agree.

The interview was done using a structured form printed for further typing by the researcher using Google forms. The researcher contacted potential participants and then performed the interviews with those who agreed to participate during a personal meeting, where it was possible to discuss their questions. The questionnaire was applied over a sample of 54 employees of an organization from the health sector in Brazil from August 27- October 20, 2018.

Table 2 shows how the respondents were classified into three different groups according to their organizational role. This table also shows the estimated size of the population and the percentage of respondents.

Table 2
Respondents

Group	Estimated Population	Interviewed	%
A – Executives	10	10	100
B - Project Management Specialists	6	5	83.3
C - Project managers or team members	100	39	39.0
∑	**116**	**54**	**46.5**

Potential participants were contacted by phone, and the objective was explained and a contact with the researcher was scheduled when the terms of confidentiality of the data and purpose of the research were presented. During the interviews, which were performed by direct contact of the researcher with the respondents, some participants spontaneously reported that the organization did not have formal and clear criteria for determining the performance evaluation of projects. The information collected regarding the criteria used by the organization in a non-systematic and informal way can be found in Figure 2.

According to the respondents interviewed, the organization's "Legality and Compliance", "Purpose and Mission", "Organizational Benefits" and "Political and Social Factors" were perceived by the respondents as being more likely to be considered by the organization for evaluation; on the other hand, "Efficiency, "Project Team Satisfaction", "Stakeholder's Satisfaction" and "Sustainability" were not perceived by the respondents to be considered.

However, the aim of this paper is to determine the relative importance of each criterion using a method to organize the balance of trade-offs, and for this purpose, we employed the AHP method.

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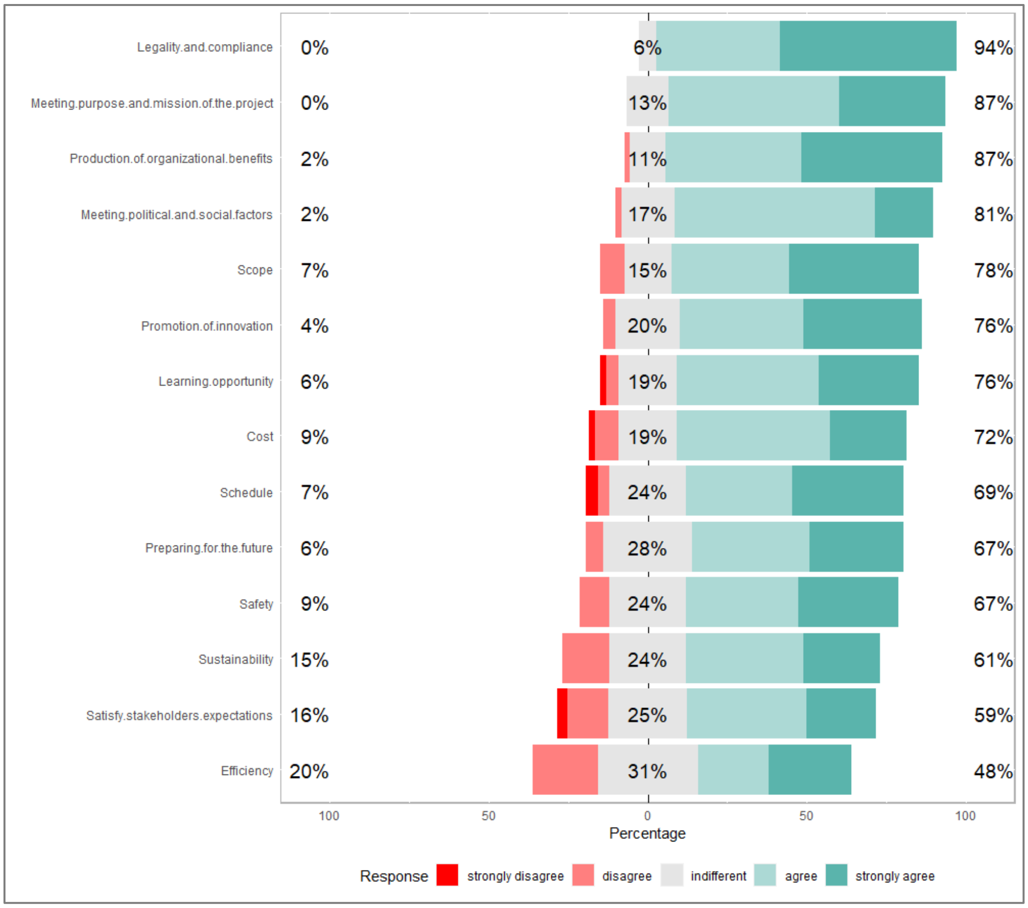

Figure 2 Project evaluation criteria

3.2 Construction of criteria hierarchy of criteria

The AHP method considers pairwise comparisons; however, when there are a large number of criteria it is more difficult to evaluate the nuances between two criteria. Thus, a hierarchy was created aggregating criteria in a structure with macro criteria and sub-criteria.

Therefore, the 16 criteria identified in the literature were aggregated into four macro criteria (C1-Iron Triangle, C2-Mean-related, C3-End-related and C4-Related to the future). This proposed structure is shown in the Figure 3.

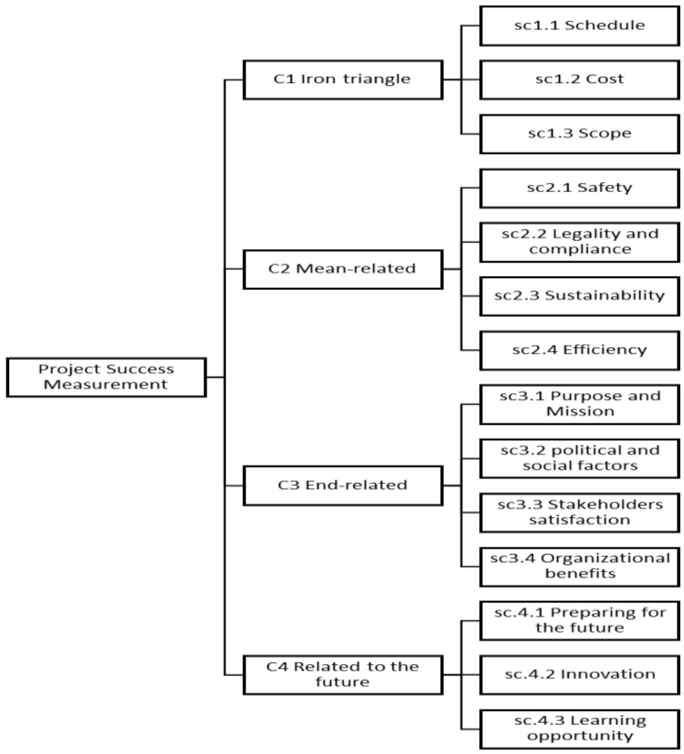

Figure 3 Project success criteria hierarchy

Next, a pairwise comparison was performed between the sub-criteria and then between the criteria.

3.3 Pairwise judgment of value from the data obtained in the survey and evaluation of the degree of consistency

The first judgment was performed by comparing the answers of the interviewed participants about Cost, Schedule, and Scope. The results of this group of traditional project success criteria also named the "Iron Triangle" in the related professional literature are shown in the Figure 4.

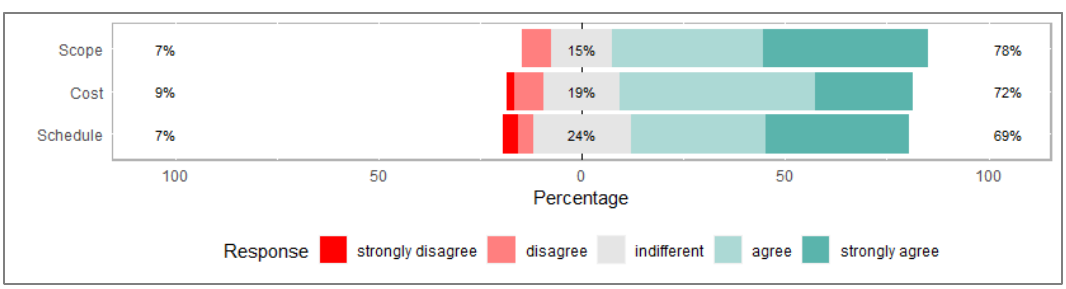

Figure 4 Agreement grade of Iron Triangle criteria

The importance between the facets of success in projects was evaluated in pairs from the data obtained in the empirical survey beginning with the sub-criteria that make up the so-called Iron Triangle, (cost, schedule and scope) using the scale of preferences (Saaty, 1980). The obtained results are shown in the pairwise comparison matrix in Table 3.

Table 3
Pairwise comparison matrix: Iron Triangle

C1 Iron triangle	sc 1.1	sc 1.2	sc 1.3	EV	NEV	λ max.	IC	RC	n	RI
sc1.1 Schedule	1	1/2	1/3	0.550	16.3%					
sc1.2 Cost	2	1	1/2	1.000	29.7%					
sc1.3 Scope	3	2	1	1.817	54.0%					
∑	**6.00**	**3.50**	**1.83**	**3.367**	**100.0%**	**3.01**	**0.00**	**0.01**	**3**	**0.58**

The consistency ratio (CR) was 0.01, which is less than the recommended limit of 0.10 or 10% (Saaty, 1980).

The same procedure was used to evaluate the criteria that compose the group mean-related criteria, which aggregates criteria that describe the way the project was done (Efficiency, Legality and Compliance, Safety, and Sustainability). Figure 5 shows the results from the interview related to this group.

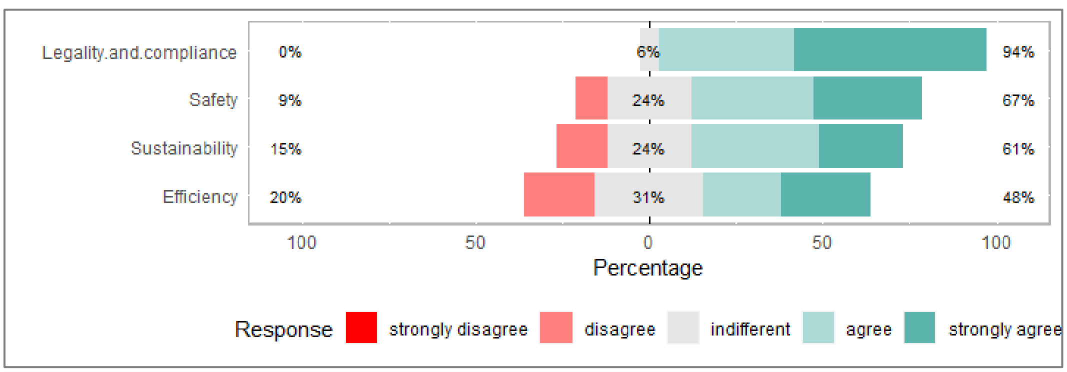

Figure 5 Agreement grade of Mean-related criteria

Then, a comparison between the sub-criteria was performed and is shown in Table 4.

Table 4
Pairwise comparison matrix: Mean-related criteria

C2 Mean-related	sc 2.1	sc 2.2	sc 2.3	sc 2.4	EV	NEV	λ max.	IC	RC	n	RI
sc2.1 Safety	1	1/7	2	3	0.962	16.0%					
sc2.2 Legality and compliance	7	1	5	7	3.956	65.8%					
sc2.3 Sustainability	1/2	1/5	1	3	0.740	12.3%					
sc2.4 Efficiency	1/3	1/7	1/3	1	0.355	5.9%					
∑	**8.83**	**1.49**	**8.33**	**14.00**	**6.014**	**100.0%**	**4.24**	**0.08**	**0.09**	**4**	**0.90**

The consistency ratio (CR) was 0.09, which is less than the recommended limit of 0.10 or 10% (Saaty, 1980).

The end-related criteria are used as an aggregation of “Meeting end user expectations”, “Meeting political and social factors”, “Meeting project team expectations”, “Meeting purpose and mission of the project”, “Meeting stakeholders’ expectations” and “Production of organizational benefits”. This group of criteria are related to the efficacy of the project. The results can be seen in Figure 6.

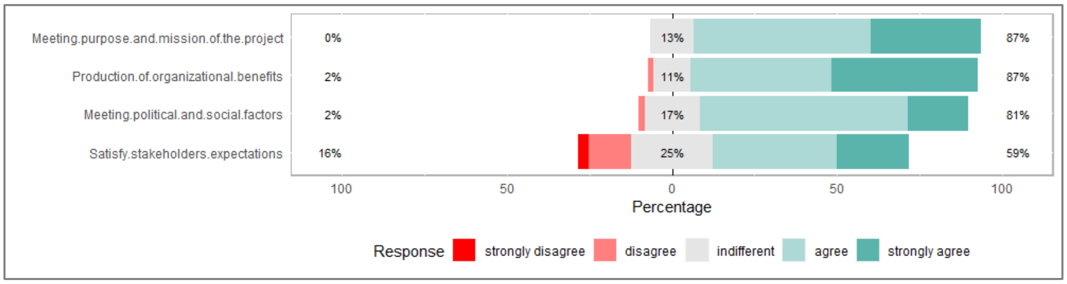

Figure 6 Agreement grade End-related criteria

The pairwise comparison of this group of criteria is shown in Table 5.

Table 5
Pairwise comparison matrix: End-related criteria

C3 End-related	sc 3.1	sc 3.2	sc 3.3	sc 3.4	EV	NEV	λ max.	IC	RC	n	RI
sc3.1 Purpose and Mission	1	3	9	2	2.711	45.1%					
sc3.2 Political and social factors	1/3	1	7	1/2	1.039	17.3%					
sc3.3 Stakeholders satisf.	1/9	1/7	1	1/7	0.218	3.6%					
sc3.4 Organizational benefits	1/2	2	7	1	1.627	27.0%					
∑	**1.94**	**6.14**	**24.00**	**3.64**	**5.595**	**93.0%**	**3.79**	**-0.07**	**-0.08**	**4**	**0.90**

The last group of criteria named “related to the future” groups criteria related to non-immediate impact (Learning opportunity, Preparing for the future and Promotion of innovation). The results are shown in Figure 7.

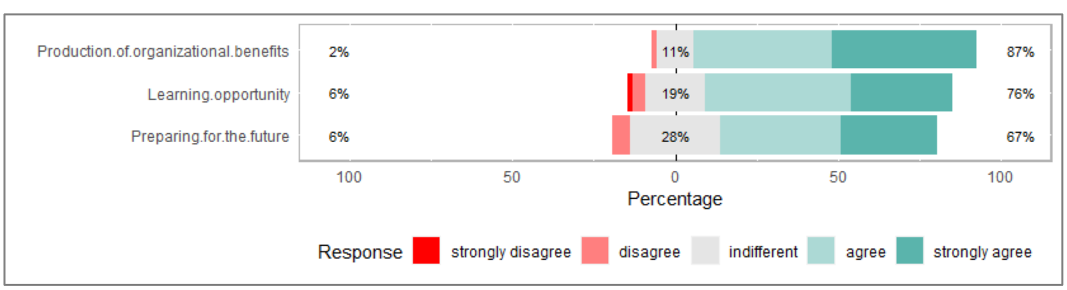

Figure 7 Agreement grade criteria related to the future

The evaluation of the data collected from the interviewed participants about this variable is organized in Table 6.

Table 6
Pairwise comparison matrix: Criteria related to the future

C4 Related to the future	sc 4.1	sc 4.2	sc 4.3	EV	NEV	λ max.	IC	RC	n	RI
sc.4.1 Preparing for the future	1	1/3	1/3	0.481	16.4%					
sc.4.2 Innovation	3	1	1	1.000	34.2%					
sc.4.3 Learning opportunity	3	1	1	1.442	49.3%					
∑	**7.00**	**2.33**	**2.33**	**2.923**	**100.0%**	**3.10**	**0.05**	**0.09**	**3**	**0.58**

The consistency ratio (CR) is 0.09, less than the recommended limit of 0.10 or 10% (Saaty, 1980).

After all the sub-criteria were evaluated, an evaluation of the criteria was performed. The results from the sub-criteria were summed to compose each top-level criterion as detailed in Table 7. The plot compares the percentage frequencies in each criterion by using the Likert scale, and the results are presented in Figure 8.

Table 7
Consolidation of sub-criteria for each criterion

Criteria / Sub-Criteria	**Answers given**				
C1 Iron triangle	**1**	**2**	**3**	**4**	**5**
sc1.1 Schedule	2	2	13	18	19
sc1.2 Cost	1	4	10	26	13
sc1.3 Scope	0	4	8	20	22
Σ	**3**	**10**	**31**	**64**	**54**
C2 Mean-related	**1**	**2**	**3**	**4**	**5**
sc2.1 Safety	0	5	13	19	17
sc2.2 Legality and compliance	0	0	3	21	30
sc2.3 Sustainability	0	8	13	20	13
sc2.4 Efficiency	0	11	17	12	14
Σ	**0**	**24**	**46**	**72**	**74**
C3 End-related	**1**	**2**	**3**	**4**	**5**
sc3.1 Purpose and Mission	0	0	7	29	18
sc3.2 Political and social factors	0	1	9	34	10
sc3.5 Stakeholders' satisfaction	1	6	15	26	6
sc3.6 Organizational benefits	0	1	6	23	24
Σ	**1**	**8**	**37**	**112**	**58**
C4 Related to the future	**1**	**2**	**3**	**4**	**5**
sc.4.1 Preparing for the future	0	3	15	20	16
sc.4.2 Innovation	0	2	11	21	20
sc.4.3 Learning opportunity	1	2	10	24	17
Σ	1	7	36	65	53

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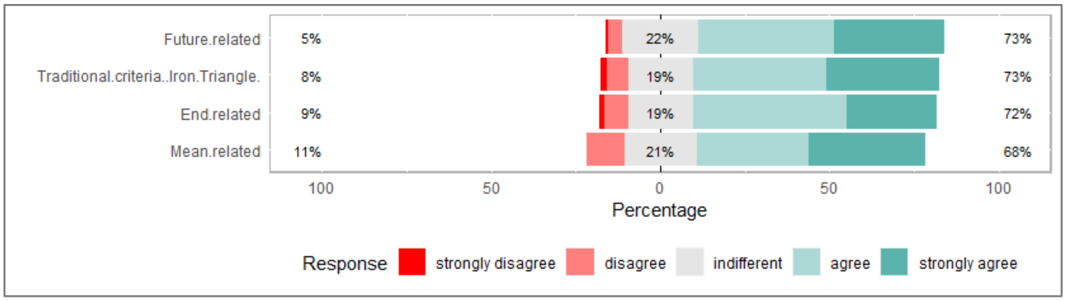

Figure 8 Agreement grade of success of project

Finally, the upper level of the AHP hierarchy was evaluated by aggregating all the responses for each component as follows in Table 8.

Table 8
Criteria and sub-criteria

Criteria (upper level)	**Sub-criteria (lower level)**
Traditional criteria (Iron Triangle)	Cost Schedule Scope
Mean-related	Efficiency Legality and compliance Safety Sustainability
End-related	Meeting political and social factors Meeting purpose and mission of the project Meeting stakeholders' expectations Production of organizational benefits
Future-related	Learning opportunity Preparing for the future Promotion of innovation

These data were used to construct the last pairwise comparison matrix shown in Table 9.

Table 9
Pairwise comparison matrix: Project success

Project Success	C 1	C 2	C 3	C 4	EV	NEV	λ max.	IC	RC	n	RI
C1 Iron triangle	1	3	2	1/2	1.316	29.2%					
C2 Mean-related	1/3	1	1/2	1/3	0.485	10.8%					
C3 End-related	1/2	2	1	1/2	0.841	18.7%					
C4 Related to the future	2	3	2	1	1.861	41.3%					
∑	3.83	9.00	5.50	2.33	4.504	100.0%	4.08	0.03	0.03	4	0.90

The consistency ratio (CR) is 0.03, less than the recommended limit of 0.10 or 10% (Saaty, 1980).

The pairwise comparisons are now completed, and it is possible to identify the weights supplied by the AHP method.

3.4 Prioritization analysis

The results are consolidated in Table 10 which shows the relative importance (weight) assigned using the eigenvector of the previous pairwise matrices, and the global weight is obtained by the multiplication of each sub criteria by the upper-level criteria, thus providing the relative importance ranking of each.

Table 10
Relative importance (weights) of criteria

Sub criteria	Weight	Global Weight
C1 Iron triangle	**29.2%**	
sc1.1 Schedule	16.3%	4.8%
sc1.2 Cost	29.7%	8.7%
sc1.3 Scope	54.0%	15.8%
C2 Mean-related	**10.8%**	
sc2.1 Safety	16.0%	1.7%
sc2.2 Legality and compliance	65.8%	7.1%
sc2.3 Sustainability	12.3%	1.3%
sc2.4 Efficiency	5.9%	0.6%
C3 End-related	**18.7%**	
sc3.1 Purpose and Mission	45.1%	8.4%
sc3.2 Political and social factors	17.3%	3.2%
sc3.5 Stakeholders satisfaction	3.6%	0.7%
sc3.6 Organizational benefits	27.0%	5.1%
C4 Related to the future	**41.3%**	
sc.4.1 Preparing for the future	16.4%	6.8%
sc.4.2 Innovation	34.2%	14.1%
sc.4.3 Learning opportunity	49.3%	20.4%

The data in Table 10 communicates the goal of this paper which is to elicit the relative importance of each criterion through the application of the AHP, a method that is able to deal with subjectivity, from the results of the empirical study at the selected organization.

Table 11 shows a list of criteria with their respective relative importance between parenthesis in descending order.

Table 11
Project success criteria ordered by relative importance

Sub criteria	Weight	Criterion	Weight	Final Weight	Classification
sc.4.3 Learning opportunity	49.3%	C4 Related to the future	41.3%	20.4%	1
sc1.3 Scope	54.0%	C1 Iron triangle	29.2%	15.8%	2
sc.4.2 Innovation	34.2%	C4 Related to the future	41.3%	14.1%	3
sc1.2 Cost	29.7%	C1 Iron triangle	29.2%	8.7%	4
sc3.1 Purpose and Mission	45.1%	C3 End-related	18.7%	8.4%	5
sc2.2 Legality and compliance	65.8%	C2 Mean-related	10.8%	7.1%	6
sc.4.1 Preparing for the future	16.4%	C4 Related to the future	41.3%	6.8%	7
sc3.6 Organizational benefits	27.0%	C3 End-related	18.7%	5.1%	8
sc1.1 Schedule	16.3%	C1 Iron triangle	29.2%	4.0%	9
sc3.2 Political and social factors	17.3%	C3 End-related	18.7%	3.2%	10
sc2.1 Safety	16.0%	C2 Mean-related	10.8%	1.7%	11
sc2.3 Sustainability	12.3%	C2 Mean-related	10.8%	1.3%	12
sc3.5 Stakeholders satisfaction	3.6%	C3 End-related	18.7%	0.7%	13
sc2.4 Efficiency	5.9%	C2 Mean-related	10.8%	0.6%	14

4. Discussion, practical applications, and limitations

One important consequence of this method is that the results could be affected because the amount of sub-criteria for each criterion was not similar. This is because the relative importance of one criterion could be reduced at the product of the eigenvalues of the criteria and sub-criteria depending on the number of sub-criteria that compose the criterion in the hierarchy. Thus, it is recommended that the structure be equilibrated.

Another observation of this study performed at a public organization is that the criterion "Legality and Compliance" shown in Table 1 was the top ranked criterion; however, by using this method it was reduced in importance to the sixth position when the criterion "Mean-related" received a lower relative importance because the other sub-criteria that compose it were rated low (Efficiency, Safety and Sustainability).

The practical implication of this work lies in the possibility of offering support for the most used criteria for the evaluation of project performance. In this way, it is possible to direct resources towards the criteria with greater sensitivity to project success.

Even though the study was carried out with a good sample of respondents, they all belong to the same organization that has a specific organizational culture, and may not, therefore, represent all organizations and their individual cultures and environments. It is also important to note that the researcher is connected to institution that was analyzed.

5. Conclusion

The main contribution of this work is to provide the relative weights of project success criteria that have been identified in the scientific literature using a method that allows the consistency of subjective evaluations to be validated. This contribution fulfills an existing gap in the field of a lack of adequate models to deal with the present subjectivity in this evaluation.

We determined the relative importance of the criteria for evaluating success in projects using the AHP method considering the responses of the 54 participants who were interviewed as follows: Learning opportunity (20.4%), Scope (15.8%), Innovation (14.1%), Cost (8.7%), Purpose and Mission (8.4%), Legality and compliance (7.1%), Preparing for the future (6.8%), Organizational benefits (5.1%), Schedule (4.0%), Political and social factors (3.2%), Safety (1.7%), Sustainability (1.3%), Stakeholders' satisfaction (0.7%), and Efficiency (0.6%).

We highlight the unexpected finding that despite the fact that the aspects of cost, schedule and scope are widely used in performance evaluation, they did not rank highly in the study. It is also important to highlight that the consistency ratio (CR) of all the evaluations was less than 10% which indicates a consistent result using the AHP method.

For further study, we propose comparative studies with similar organizations in order to identify possible differences in success criteria prioritization between them. We also recommend extending this work by using the ANP to see the relationships among the criteria.

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