Assessment of innovation management systems in established innovative companies: a conceptual model based on ISO 56002:2019 standard

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Abstract. This paper presents an assessment model designed to help companies achieve excellence in innovation management. The primary goal is to evaluate their level of maturity concerning the ISO 56002:2019 standard clauses and items. An empirical study was conducted at Light SESA, a Brazilian electric power sector company, to demonstrate the model's applicability. The methodology comprises the following steps: (i) conducting a thorough literature review and documentary analysis on the research subjects; (ii) defining the analytical structure based on the ISO 56002:2019 framework; (iii) applying the Analytic Network Process (ANP) method to assigning weights to dimensions and factors that integrate the assessment structure; (iv) creating, pretesting a questionnaire to be applied to senior leaders and RD&I project managers of a given company to evaluate its level of maturity concerning the ISO 56002:2019 standard clauses and items; (v) using the fuzzy logic to compute the collective judgements, avoiding biased decisions and assessment results; (vi) employing the Importance-Performance Analysis (IPA) method to identify priority areas for improving the company's innovation management system. The main result of this work is a robust model for assessing the maturity of innovation management systems of innovative companies that seek to improve their innovation capacity and performance.

1. Introduction

The innovation capability of companies refers to their capacity to understand changing business environments, identify market opportunities, and internally or collaboratively create new knowledge and solutions. Innovation can be effectively managed through innovation management systems, which have emerged as standardized tools to help them navigate the complexities of the innovation process, systematize their activities, and enhance management efficiency [1- 6].

These systems first appeared in European countries such as Spain, Portugal, Denmark, the United Kingdom, France, and Ireland [1-3]. At the regional level, the European Committee for Standardization released the European Standard CEN-TS 16555-1 (Innovation Management: Innovation Management System) in July 2013 [7]. More recently, in July 2019, the ISO 56002:2019 standard (Innovation management: Innovation management system – Guidance) was published, following a five-year international standardization process involving 52 countries and approximately

100 innovation management experts. This document guides establishing, implementing, maintaining, and continually improving an innovation management system in established organizations [8].

Based on the following assumptions: (i) the ISO 56002:2019 standard serves as the international reference for guiding the establishment, implementation, maintenance, and continual improvement of an innovation management system in established organizations; (ii) the combination of decision-making methods significantly contributes to the practical assessment of innovation management systems by companies seeking to improve their innovative capacity and innovation performance; (iii) employing an assessment model based on the ISO 56002:2019 framework can help innovative companies from different sectors identify critical issues and opportunities for strengthening their capacity to manage innovation systems, this paper aims to address the following main research questions:

(i) How can the maturity level of innovation management systems of established innovative companies be assessed in light of the clauses and items of ISO 56002:2019 standard?

(ii) What assessment dimensions and factors based on the ISO 56002:2019 framework should be considered in the analytical structure of a model designed to evaluate the innovation management system of a given company?

(iii) To what extent can the combination of decision-making methods with fuzzy logic contribute to the efficiency of the assessment process of innovation management systems of innovative companies, considering the inherent complexity and multidimensionality of it?

Addressing these research questions, this paper proposes an assessment model for evaluating innovation management systems of innovative companies based on the ISO 560002:2019 framework [8], which combines two decision-making methods and fuzzy logic theory. An empirical study was conducted at Light SESA, a Brazilian electric power sector company, to empirically demonstrate the model's applicability.

The paper is structured in six sections, including this introduction. Section 2 synthesizes the literature review covering previous works published between 2010 and 2023 about the central research themes. Section 3 briefly presents the research design and methods adopted. Section 4 introduces the assessment model for evaluating innovation management systems of established innovative companies based on the ISO 56002:2019 framework. Section 5 presents an empirical study carried out at Light SESA to demonstrate the practical applicability of the assessment model within a real corporate and business context. In Section 6, we discuss the key differentiating characteristics of the proposed model compared to the methodological approaches covered in the literature review and synthesize the concluding remarks.

2. Literature review

The literature review encompassed previous works published between 2010 and 2023 [1-6, 9-18], focusing on management system standards for innovation, with specific attention given to the ISO 56002:2019 standard. To conduct this review comprehensively, we searched international scientific databases such as Scopus, Web of Science, Science Direct, and Google Scholar. A backward search was also performed by analyzing the references cited in the most relevant articles. We aimed to identify relevant empirical studies that evaluated innovation management processes or systems based on applicable standards in established organizations from various contexts and countries [9-18].

The comparative analysis of the selected empirical studies covered the following aspects: (i) the study's objective; (ii) the region and sector(s) where the evaluation model was applied; (iii) the dimensions/variables considered; and (iv) the methodological approaches and methods adopted.

These previous studies provide valuable insights into the understanding of the subject while also reveal uncovering gaps in the literature concerning the evaluation of innovation management systems based on the ISO 56002:2019 framework. Notably, only one of the reviewed studies, which focused on Science and Technology (S&T) institutions [18], utilized a multicriteria approach capable of analyzing cause-and-effect relationships and feedback between the clauses of the standard at the primary level and the items subordinate to each clause at the secondary level. However, even having chosen an appropriate multicriteria decision-making method [19], this study did not include fuzzy logic [20] in their assessment model to avoid biased judgments and results when evaluating the maturity level of the innovation management system of these institutions.

Furthermore, the literature review covered decision-making methods to support selecting the most appropriate methods for the intended modelling. Also, reference works on organizational maturity models reviewed in [21] were analyzed to aid in establishing a five-point scale for maturity, which should be incorporated into the conceptual model.

3. Research design and methodology

This Section outlines the research methods used to tackle the research questions in Table 1. The research design is structured into three phases and six stages, following a procedural model inspired by Rocha et al. [22]. This approach ensures a well-defined structure and an approved course of action for the research. The research phases include (i) motivation, (ii) development, and (iii) validation.

Table 1. Research design

Phase	Stage	Research questions [Section]
Motivation	Problem definition and the rationale for the research.	What are the reasons that justify the development of a conceptual model to assess innovation management systems in established innovative companies using the ISO 560002:2019 framework? [Section 1]
Development (What and How?)	State of research on central themes and identification of research gaps and unsolved problems.	What significant gaps exist in the knowledge regarding monitoring and evaluating innovation management systems of established innovative companies based on standards? [Section 2]
	Definition of the research methodology.	How can an assessment model based on the ISO 56002:2019 standard be developed and empirically validated within a real corporate and business context? [Section 3] What decision-making methods should be chosen for the intended modelling? [Section 3]
	Development of an assessment model for evaluating innovation management systems of established innovative companies based on the ISO 56002:2019 framework.	How can we determine the maturity level of innovation management systems in established innovative companies, using the framework of the ISO 56002:2019 standard and avoiding biased results? [Section 4] What assessment dimensions and factors, aligned with the ISO 56002:2019 framework, would be incorporated into the analytical structure of an assessment model designed to evaluate the innovation management system within a specific company? [Section 4]
Validation (How to demonstrate the applicability of the assessment model?	Application of the assessment model in the context of Light SESA, a company in the Brazilian electric power sector	Can the applicability of the proposed assessment model be demonstrated through the development of an empirical study conducted at Light SESA involving senior leaders and RD&I project managers? [Section 5] What is the current maturity level of Light SESA's innovation management system? [Section 5]
	Discussion of the empirical results and implications of the adoption of the model in others organizations.	Will the results of the empirical study conducted at Light SESA in Brazil effectively demonstrate the applicability of the proposed assessment model? [Section 5] What are the key differentiating factors of the proposed model compared to the methodological approaches covered in the literature review in Section 2? [Section 5]

The first two stages involved conducting a comprehensive literature review and documentary analysis of scientific articles and normative documents published between 2010 and 2023, as mentioned in Section 2. Afterwards, research gaps were identified, and the methodology was defined and detailed in the third stage.

To effectively address the research gaps and develop an assessment model for evaluating the maturity of innovation management systems, the ISO 56002:2019 framework [8], along with two decision-making methods – the Analytic Network Process (ANP) [19] and the Importance Performance Analysis (IPA) [23], were chosen in the fourth stage.

The ANP is a decision-making method used to analyze complex systems with interdependent relationships. It allows the researcher to model and evaluate the interactions among different system elements, considering both their direct and indirect impacts on each other. It was selected from various multicriteria methods, primarily due to the ISO 56002:2019 framework's comprehensive nature, consisting of seven clauses and 28 items that can be interconnected in multiple ways. By forming a network using these elements, interdependent relationships and feedback within and between clusters can be incorporated. The concept of a supermatrix is introduced, representing the influence of network elements on each other through adjusted relative importance weights.

According to Saaty [19], the ANP method comprises the following main steps: (i) determining the network model, (ii) determining element and cluster importance weights, and (iii) calculating the limit matrix and resulting weighting of network elements and clusters. The first step involves representing the decision problem using a network structure, which requires an in-depth understanding of the problem by decision-makers. The tasks for constructing the network model include determining network elements, logical groups of elements (clusters), and the influence network by creating a zero-one interfactorial dominance matrix regarding the network elements.

The zero-one interfactorial dominance matrix is crucial for the subsequent steps, as it captures the influences between elements. The decision-makers' accurate identification of influences is vital to preserving valuable information within the model. For this reason, decision-makers should be asked to identify these influences precisely.

In the second step, pairwise comparisons of elements are conducted using Saaty's nine-point scale (Table 2). After consolidating judgments and preferences from decision-makers or experts, a comparison matrix of multiple valuation criteria can be constructed.

Table 2. Saaty's nine-point scale [19]

Scale	Linguistic scale
1	Equally important
2	Equally to moderately more important
3	Moderately more important
4	Moderately to strongly important
5	Strongly important
6	Strongly to very strongly more important
7	Very strongly more important
8	Very strongly more important to absolutely important
9	Absolutely important

To implement the ANP method, managers or experts who provide judgments or preferences must undergo a consistency test based on the pairwise comparison matrices' consistency ratios (C.R.). The C.R. of a pairwise comparison matrix is the ratio of the consistency index to the corresponding random value. For more details, refer to [19].

The corresponding pairwise comparison matrices are generated to obtain the unweighted supermatrix's eigenvectors. The priority value associated with a particular cluster determines the priorities of the cluster elements it influences (in the unweighted supermatrix), and subsequently, the weighted supermatrix is generated.

To create the weighted supermatrix, the unweighted supermatrix is combined with the control hierarchy matrix, which requires building an n*n matrix, where n is the number of clusters in the network. The control hierarchy matrix is established by choosing a cluster Ci and then pairwise comparing it (with AHP) to all other clusters connected with Ci to determine their impact. This process results in the weighted supermatrix, which is then limited, gradually consolidating interdependency and relative weights [19].

The third step of constructing the ANP model involves calculating the limit matrix and prioritizing the network elements. The limit matrix is obtained by raising the weighted supermatrix to successive powers. In this work, the network elements consist of 28 items associated with the seven clauses of the ISO 56002:2019 standard [8]. These 28 items were logically grouped into clusters corresponding to the mentioned clauses. The weights of the 28 items were calculated with the support of the Super Decisions® software [24].

Additionally, assessment data should be gathered from RD&I decision-makers within a given innovative company and then synthesized to obtain the final assessment results regarding the maturity of its innovation management system. Subsequently, the second decision-making method (IPA) [23] was employed in the last phase of the proposed model. The IPA method has been used to identify areas that require improvement in a given system or organization. It helps assess the importance of various factors or criteria and their corresponding performance to identify priorities for action. Concerning the proposed model, the use of IPA aimed to efficiently allocate resources to improve the maturity level of the innovation management system of a given established company.

4. The assessment model based on the ISO 56002:2019 framework

Under the methodology described in Section 3, the assessment model comprises eight stages, each of which is elaborated and explained comprehensively in the subsequent subsections.

4.1. Stage 1: Establishing the analytical structure based on the ISO 56002:2019 framework

The analytical structure was established and built upon ISO 56002:2019 framework [8]. The clauses in this standard align with the assessment dimensions of the proposed model, while the requirements represent the assessment factors, as illustrated in Table 3 and Figure 1.

Table 3. Analytical structure based on the ISO 56002:2019 framework [8]

Control layer		**Network layer**
Target	**Assessment dimensions**	**Assessment factors**
Maturity assessment (A) based on the ISO56002: 2019 framework	Context of the organization [C1]	Understanding the organization and its context (C11)
		Understanding the needs and expectations of interested parties (C12)
		Determining the scope of the innovation management system (C13)
		Establishing the innovation management system (C14)
	Leadership [C2]	Leadership and commitment (C21)
		Innovation policy (C22)
		Organizational roles, responsibilities, and authorities (C23)
	Planning [C3]	Actions to address opportunities and risks (C31)
		Innovation objectives and planning to achieve them (C32)
		Organizational structures (C33)
		Innovation portfolios (C34)
	Support [C4]	Resources (general, people, time, knowledge, finance, and infrastructure) [C41]
		Competence [C42]
		Awareness [C43]
		Communication [C44]
		Documented information [C45]
		Tools and methods [C46]
		Strategic intelligence management [C47]
		Intellectual property management [C48]
	Operations [C5]	Organizational planning and control [C51]
		Innovation initiatives [C52]
		Innovation processes (innovation funnel) [C53]
	Performance evaluation (C6)	Monitoring, measurement, analysis, and evaluation [C61]
		Internal audit [C62]
		Management review [C63]
	Improvement (C7)	General [C71]
		Deviation, non-conformity, and corrective action [C72]
		Continual improvement [C73]
1 target	**Seven clauses**	**28 requirements**

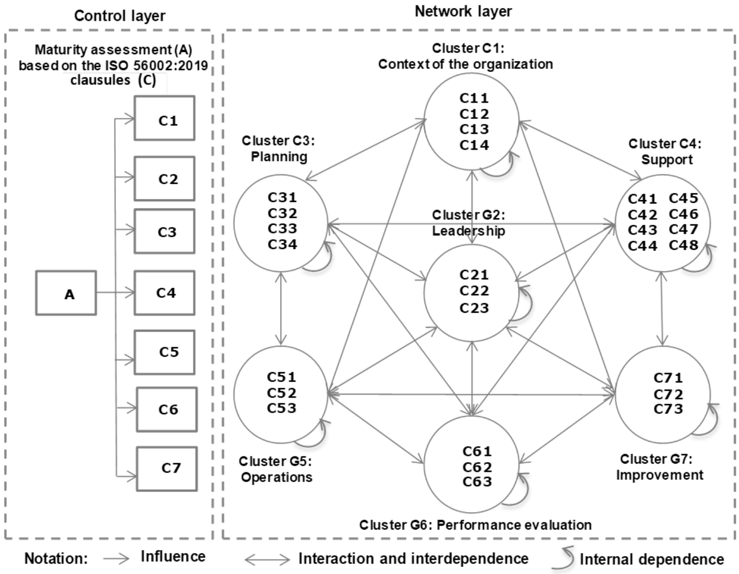

Figure 1. The network analytical structure based on the ISO 56002:2019 framework [8]

A zero-one interfactorial dominance matrix is constructed to determine the relationships between the assessment factors. In this matrix, elements are assigned values of 1 or 0, signifying the presence or absence of influence between factors. The matrix is organized with the 28 assessment factors grouped into seven clusters [19].

4.2. Stage 2: Designing the questionnaire for pairwise comparisons of assessment dimensions and factors

During this stage, a questionnaire for conducting pairwise comparisons of the network elements and clusters should be developed and pretested to assess its clarity, appropriateness for the respondents, the time required to answer the questions, and potential obstacles that may arise during its implementation.

The Saaty's nine-point scale (Table 2) is utilized for the pairwise comparisons of the network elements and clusters, according to the mentioned zero-one interfactorial dominance matrix. These comparisons should be carried out by innovation managers and teams involved in evaluating the innovation management system of a given company.

4.3. Stage 3: Assigning weights to the assessment factors

Once the judgments and preferences have been consolidated and the consistency ratios (C.R.) tested, the corresponding pairwise comparison matrices can be generated to calculate the resulting eigenvectors [19]. To achieve this, a supermatrix is compiled, containing sub-matrices representing the seven clusters and necessary elements in the order on the left and upper sides of the matrix. If the aggregate of the column vectors in the supermatrix is not equal to 1, it is referred to as an unweighted supermatrix, which can be converted into a weighted supermatrix through specific procedures.

The weight associated with each cluster determines the priorities of the cluster elements (in the unweighted supermatrix) on which they exert influence. By using this information, the weighted supermatrix is derived. Ultimately, the weighted supermatrix is obtained by combining the unweighted supermatrix with the control hierarchy matrix, which results from the pairwise comparisons of the seven guidelines, using Saaty's scale, as shown in Table 2. Accordingly, a 7*7 sub-matrix is constructed for weighting the seven clusters, which leads to the calculation of a weighted supermatrix.

4.4. Stage 4: Calculating the limit supermatrix and resulting weights of the assessment factors

In this stage, the limit supermatrix is obtained by performing a power operation on the weighted supermatrix, and its weighted value converges towards stability. This gradual consolidation of interdependency and relative importance weights is achieved. Finally, with the assistance of the Super Decisions software [24], the weights of the 28 assessment factors are calculated, as described before.

4.5. Stage 5: Designing the maturity five-point scale for assessing test and calibration laboratories

A specially designed five-point maturity scale for evaluating the maturity of an innovation management system at the organizational level was proposed in [18] based on the common characteristics identified from various maturity models [21]. The maturity scale presented in Table 4 should be adopted in this stage.

Table 4. Maturity scale to assess the maturity of an innovation management system at the organization level

Maturity Level	Scale	Description
Nothing, informal, or *ad hoc*	1	The capability is not established or established in an informal or ad hoc manner. It is not defined or managed.
Managed at the basic level	2	The capability is established at a basic level. It is, to some extent, but not entirely managed.
Defined and managed	3	The capability is defined and established. It is managed in a proactive manner.
Systematically managed	4	The capability is defined, established, and aligned. It is systematically and dynamically managed.
Optimized	5	The capability is continuously improved and optimized. It is managed based on active monitoring, feedback, and learning.

Source: [18].

4.6. Stage 6: Designing the questionnaire for data collection

In this stage, the design of a second questionnaire considers the inclusion of the network elements (28 assessment factors), the seven clusters (assessment dimensions), and the maturity scale proposed in stage 5 (Table 4). As with the first questionnaire, a pretesting is necessary to assess its clarity, suitability for the respondents, and the time required to answer the questions. Once the questionnaire has been validated, it can be administered to senior leaders and RD&I project managers within a given organization. If multiple experts are participating in the evaluation process, fuzzy logic [20] should be employed to compute the collective judgements, avoiding biased decisions and assessment results.

4.7. Stage 7: Calculating the overall maturity level of a given innovative company

In this stage, the overall maturity level of an innovation management system within a given innovative company is calculated. The synthesis of importance weights of assessment factors (from stage 4) and the rating scores (based on the maturity scale defined in Table 4) leads to the final results pertaining to the maturity of the company's innovation management system. As mentioned before, if multiple experts are participating in the evaluation process, it is recommended the use of fuzzy logic.

The foundation of fuzzy logic [20] lies in the use of linguistic variables and fuzzy rules to handle imprecise and uncertain data. Instead of using precise numerical values, fuzzy logic employs linguistic terms to represent different degrees of truth or membership. Table 5 presents the representation of the linguistic variable 'degree of maturity in relation to the items of the ISO 56002:2020 standard.' It includes the linguistic terms and their corresponding parameters of the triangular fuzzy numbers for each term (*lwi*, *uwi*, and *mwi*).

Furthermore, radar-type charts (as depicted in Figure 2) can be generated from the results for each of the seven assessment dimensions, following the ISO 56004:2020 recommendations [25]. These charts provide a visual representation of the company's maturity levels across different aspects of innovation management.

Table 5. Maturity scale to assess the maturity of an innovation management system with triangular fuzzy numbers

Linguistic term for maturity levels	Maturity scale	Triangular fuzzy numbers		
		lwi	***uwi***	***mwi***
Nothing, informal, or *ad hoc*	1	1	1	2
Managed at the basic level	2	1	2	3
Defined and managed	3	2	3	4
Systematically managed	4	3	4	5
5. Optimized	5	4	5	5

4.8. Stage 8: Mapping decision-making zones for establishing targets and action plans

The objective of this stage is to chart decision-making zones, which will enable to establish targets and action plans for enhancing the maturity level of a company's innovation management system, using the IPA method [23]. Each standard clause will be depicted in a two-dimensional space, with the horizontal axis indicating its importance (calculated weights for respective assessment factors), and the vertical axis representing its performance (corresponding maturity levels). The four decision-making zones are: (i) appropriate, (ii) improvement needed, (iii) urgent action, and (iv) excess [23].

By utilizing the IPA matrices, senior leaders and RD&I project managers can assess the situation of the associated factors in each assessment dimension concerning the four decision zones. These visual matrices facilitate a comprehensive understanding of areas that require focus and improvement and also areas where the company is performing well.

4.9. Stage 9: Elaborating the assessment report

The last stage is dedicated to creating a comprehensive report that includes all the assessment results of the company. This report will also incorporate action plans related to specific targets aimed at enhancing the maturity level of the company's innovation management system.

5. Application in an innovative company from the Brazilian electricity sector

In order to showcase the effectiveness of the proposed model, we performed an empirical study at Light SESA [26] together with its senior leaders and RD&I project managers. This study enabled us to demonstrate the practical applicability of the assessment model within a real corporate and business context.

The primary questions addressed in this empirical study were: "What is the maturity level of the Light SESA's innovation management system?" and "What are the key challenges that this company must address to improve its innovation management system, and what recommendations should be provided to senior leadership and RD&I project managers to enhance the outcomes and impacts derived from successful RD&I projects?".

Following the stages of the assessment model described in Section 3, initially, we obtained the hierarchical control matrix (7 clauses x 7 clauses) and the interfactorial dominance matrix (28 items x 28 items of the ISO 56002:2019 framework).

With all the paired comparison forms completed by senior leadership and RD&I project managers at Light SESA, the Super Decisions® software was used to calculate the weights of all 28 assessment factors, following the steps described in its manual [24]. As a result, three super matrixes were obtained: (i) the original weightless supermatrix; (ii) the weighted supermatrix; and (iii) the limiting supermatrix.

The original unweighted supermatrix, obtained from paired comparisons between the 28 assessment factors, was composed of priority vectors organized in columns. The weighted supermatrix originated from the product between the weights of the clusters (assessment dimensions) and by their counterparts in the unweighted supermatrix. The stochastic limiting supermatrix is generated by raising the power-weighted supermatrix successively until its convergence. Thus, the final weights of the 28 items of the standard that make up the self-assessment model were calculated. Due to space limitations, these supermatrixes could not be presented in this paper, but they can be accessed in [27].

5.1. Final weights to the assessment factors that integrate the proposed framework

After completing all the paired comparisons, as described in item 4.4, the Super Decisions® software was utilized to calculate the weights of the 28 assessment factors (Table 6). The corresponding calculations can be found in [27].

Table 6. Final weights of the 28 assessment factors [27]

Network layer Assessment factors	Final weights
Understanding the organization and its context (C11)	1.45
Understanding the needs and expectations of interested parties (C12)	1.05
Determining the scope of the innovation management system (C13)	0.73
Establishing the innovation management system (C14)	0.77
Leadership and commitment (C21)	1.76
Innovation policy (C22)	0.42
Organizational roles, responsibilities, and authorities (C23)	0.82
Actions to address opportunities and risks (C31)	1.68
Innovation objectives and planning to achieve them (C32)	0.96
Organizational structures (C33)	0.84
Innovation portfolios (C34)	0.52
Resources (general, people, time, knowledge, finance, and infrastructure) [C41]	1.56
Competence [C42]	1.61
Awareness [C43]	0.81
Communication [C44]	0.32
Documented information [C45]	0.38
Tools and methods [C46]	0.43
Strategic intelligence management [C47]	2.20
Intellectual property management [C48]	0.70
Organizational planning and control [C51]	0.71
Innovation initiatives [C52]	1.37
Innovation processes (innovation funnel) [C53]	0.92
Monitoring, measurement, analysis, and evaluation [C61]	1.36
Internal audit [C62]	0.19
Management review [C63]	1.45
General [C71]	1.05
Deviation, non-conformity, and corrective action [C72]	0.84
Continual improvement [C73]	1.12
28 requirements	

5.2. Overall maturity of the innovation management of Light SESA and IPA matrices

Following the determination of the final weights for the 28 items, the participants in the empirical study were individually asked to assess the level of maturity for each assessment factor. They assigned a grade from 1 to 5, using the maturity scale presented in Table 4. Afterwards, fuzzy logic was employed, as described here in item 4.7, to establish the overall maturity level of the innovation management system of Light SESA. The overall maturity was rated at 3.2. Additionally, radar-type charts were employed to visually represent the maturity levels based on the assessment factors for each standard clause. As proposed in item 4.8, IPA matrices were built to chart decision-making zones concerning each assessment dimension, which will enable to establish targets and action plans for enhancing the maturity level of Light SESA's innovation management system.

6. Discussion and final remarks

This paper presented an assessment model built upon the ISO 56002:2019 framework to evaluate the maturity of innovation management systems in established innovative companies as a natural unfolding of previous research conducted within the scope of the Graduate Program in Metrology at PUC-Rio, focusing on S&T institutions [18]. This study highlights the combination of fuzzy logic and two decision-making methods as a differential characteristic compared to the model developed in [18].

Based on the empirical results from the Light SESA's application, it is a relevant tool for diagnosing innovative companies' maturity level of innovation management systems. Because of the complexity, multidimensionality and uncertainty inherent in this type of evaluation, fuzzy logic confers reliability to the assessment process, reducing subjectivity and avoiding the risk of bias in judgments. The results presented here indicate that the proposed model, combining fuzzy logic and two decision-making methods, can help innovative companies identify areas where their innovation management systems need improvement and can subsequently enhance their innovation capacity and performance.

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