ACTA IMEKO
ISSN: 2221-870X
June 2026, Volume 15, Number 2, 1 - 9

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

Felippe Vicencio Gomes[1], Maria Fatima L. de Almeida[1]

[1] *Graduate Program in Metrology, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, 22451-900, Brazil*

ABSTRACT
This study presents a comprehensive assessment model designed to facilitate organizational excellence in innovation management through a systematic evaluation of maturity levels vis-à-vis the ISO 56002:2019 standard clauses and items. The practical applicability of the model was validated through an empirical investigation conducted at Light SESA, a prominent organization in the Brazilian electricity sector. The methodological framework encompasses six interconnected phases: (i) an extensive literature review and documentary analysis of pertinent research domains; (ii) development of an analytical framework based on ISO 56002:2019 parameters; (iii) implementation of the Analytic Network Process (ANP) for weight attribution to dimensional and factorial components within the assessment structure; (iv) design and validation of a survey instrument targeting senior leadership and RD&I project managers to evaluate organizational maturity relative to ISO 56002:2019 requirements; (v) application of fuzzy logic principles for processing collective judgments, thereby mitigating assessment bias; and (vi) utilization of Importance-Performance Analysis (IPA) methodology to identify priority areas for innovation management system enhancement. The primary contribution of this research is a robust, empirically validated model for assessing innovation management system maturity in organizations seeking to enhance their innovative capabilities and performance metrics.

Section: RESEARCH PAPER

Keywords: innovation management system; self-assessment model; multicriteria decision-making methods; NBR ISO 56002:2019 standard

Citation: F. V. Gomes, M. F. L. de Almeida, Assessment of innovation management systems in established innovative companies: A conceptual model based on ISO 56002:2019 standard, Acta IMEKO, vol. 15 (2026) no. 2, pp. 1-9. DOI: 10.21014/actaimeko.v15i2.2032

Section Editor: Carlos Hall, PósMQI/PUC-Rio, Rio de Janeiro, Brazil

Received December 9, 2024; **In final form** September 22, 2025; **Published** June 2026

Corresponding author: Maria Fatima Ludovico de Almeida, e-mail: fatima.ludovico@puc-rio.br

1. INTRODUCTION

Organizations' innovation capability encompasses their capacity to comprehend evolving business environments, identify market opportunities, and generate new knowledge and solutions, either independently or through collaborative endeavours. Innovation management systems have emerged as standardized frameworks for navigating the complexities of innovation processes, systematizing organizational activities, and enhancing management efficiency [1]–[6].

These systems originated in European nations, including Spain, Portugal, Denmark, the United Kingdom, France, and Ireland [1]–[3]. At the regional level, the European Committee for Standardization introduced the European Standard CEN-TS 16555-1 (Innovation Management: Innovation Management System) in July 2013 [7]. Subsequently, in July 2019, following a comprehensive five-year international standardization process involving 52 countries and approximately 100 innovation management experts, the ISO 56002:2019 standard (Innovation Management: Innovation Management System – Guidance) was published, providing a framework for establishing, implementing, maintaining, and continuously improving innovation management systems in established organizations [8].

This study is based on three fundamental assumptions: (i) ISO 56002:2019 serves as the international benchmark for guiding the establishment, implementation, maintenance, and continuous improvement of innovation management systems in established organizations; (ii) the integration of decision-making methodologies substantially enhances the practical assessment of innovation management systems for organizations seeking to improve their innovative capacity and performance; and (iii) implementing an assessment model based on the ISO 56002:2019 framework can assist innovative organizations across sectors in identifying critical issues and opportunities to strengthen their innovation management capabilities.

Consequently, this study addresses three principal research questions:

(i) How can the maturity level of innovation management systems in established innovative organizations be evaluated relative to ISO 56002:2019 standard clauses and items?

(ii) What assessment dimensions and factors derived from the ISO 56002:2019 framework should be incorporated into the analytical structure of a model designed to evaluate organizational innovation management systems?

(iii) To what extent can the integration of decision-making methods with fuzzy logic enhance the efficiency of an innovation management system assessment, considering its inherent complexity and multidimensionality?

In response to these research questions, this study proposes an assessment model for evaluating organizational innovation management systems based on the ISO 56002:2019 framework [8], integrating the two decision-making methods with fuzzy logic theory. The model's practical applicability is demonstrated through an empirical study conducted at Light SESA, a Brazilian electric power sector organization.

This paper is structured into seven sections, including an introduction. Section 2 presents a literature review from 2008 to 2023, concerning the central research themes. Section 3 describes the research design and methodological approach. Section 4 presents the proposed assessment model, based on the ISO 56002:2019 framework. Section 5 details the empirical study at Light SESA, demonstrating the model's practical applicability in a corporate context. Section 6 discusses the distinguishing characteristics of the model relative to existing methodological approaches, and Section 7 presents the conclusions.

2. LITERATURE REVIEW

The literature review encompasses scholarly works published between 2008 and 2023, focusing on innovation management system standards, with particular emphasis on the ISO 56002:2019 framework. The primary objective was to identify significant empirical studies that evaluated innovation management processes or systems based on applicable standards across diverse organizational contexts and geographical regions. For that, a comprehensive review methodology was implemented, utilizing international scientific databases including Scopus, Web of Science, Science Direct, and Engineering Village. Additionally, backward citation analysis was conducted on highly relevant articles to ensure comprehensive coverage [9]–[23].

Canas and Gomes [9] examined in 2008 Portugal's leading highway concession company (Brisa), focusing on the process of adaptation to the NP 4457 standard requirements. That same year, Pellicer et al. [10] conducted a survey analyzing research, development, and innovation management across 105 Spanish construction companies, emphasizing process normalization and certification. They identified consistent growth in innovation management system implementation, paralleling earlier trends with ISO 9000 and ISO 14000 families, attributed to competitiveness factors and fiscal benefits.

Rojas [11] proposed a methodology for implementing the UNE 166002 standard in Venezuelan small- and medium-sized industries, analyzing innovation management data from 30 manufacturing companies in Lara state. This study identified leadership, resource management, processes, performance evaluation, and continuous improvement as critical factors.

Pimentel [12] evaluated the Portuguese Air Force's adherence to NP 4457 requirements and concluded that implementation would enhance innovation and organizational communication.

Mir and Casadesus [19] investigated the UNE 166002 standard's implementation in a Spanish manufacturing company and reported improved innovation, internal technology transfer procedures, and company performance through innovative products and services. However, they noted challenges regarding documentation requirements and employee adaptation, particularly for those with limited innovation expertise.

González [13] developed a methodology for implementing an R&D&I system aligned with the UNE 166002 requirements and ISO/IEC 15504 maturity level 2. In turn, Pellicer et al. [14] analyzed the organizational impact of innovation process standardization through the same standard in a construction company, highlighting essential changes in internal regulations and procedures, with leadership increasingly recognizing the importance of standardized innovation management.

Cantú et al. [15] assessed NMX-GT-003-IMNC compliance in 19 Mexican technology park companies.

Gomes [16] identified the motivations for NP 4457 certification, including competitive advantage and process improvement, while Guedes [17] examined the effects of adopting this standard across cultural, social, organizational, and financial dimensions in 12 companies, noting insufficient data for a comprehensive evaluation three years post-implementation.

Other studies have focused on sector-specific applications and their integration into existing management systems. For example, Josef et al. [18] compared Volvo's innovation management system with CEN-TS 16555-1, whilst Mir et al. [19] studied the impact of UNE 166002 across 73 manufacturing companies and demonstrated its direct effects on innovative capacity and business performance.

Garechana et al. [20] employed text mining to analyze innovation management standardization effects across 12 companies, confirming the alignment with open innovation objectives.

Contemporary research has increasingly addressed implementation challenges and success factors. Santos et al. [21] investigated value generation through quality and innovation, highlighting competitive advantage as a key motivation for NP 4457 adoption, while identifying challenges such as inadequate methodologies for innovation and knowledge management, and insufficient leadership engagement.

Based on the ISO 56002:2019 framework, Santos and Almeida [22] presented a comprehensive self-assessment model for evaluating innovation management systems within science and technology institutions (STIs). The model employs the Analytic Network Process (ANP) and Importance-Performance Analysis (IPA) methodologies to create a robust evaluation framework. To validate the model's efficacy, the authors conducted an empirical investigation within a Brazilian governmental STI. The proposed conceptual framework, coupled with the empirical findings from its practical application, offers established STIs a systematic approach to identifying critical challenges and opportunities for enhancing their innovation management capabilities. This structured evaluation mechanism enables institutions to optimize their innovation processes and achieve desired outcomes more effectively.

Van Than and Hiep [23] conducted a comprehensive investigation into the innovation management landscape among Vietnamese enterprises, examining critical factors influencing organizational innovation management practices within national business context. Their empirical analysis, grounded in dimensions specified by the ISO 56002:2019 standard, revealed that leading Vietnamese enterprises demonstrate the implementation of numerous innovation management requirements based on this normative framework. Notably, their findings indicated a paradoxical relationship between organizational scale and standard implementation: larger enterprises exhibited more significant challenges in operationalizing the ISO 56002 requirements, contrary to conventional assumptions about resource availability and implementation capacity. This observation contributes to the broader discourse on the relationship between organizational size and innovation management system implementation organizations from emerging economies.

This chronological synthesis demonstrates the evolution of innovation management standardization research, revealing consistent themes around implementation challenges, organizational impacts, and success factors across different industrial contexts and geographical regions, while simultaneously revealing significant gaps in the literature regarding innovation management system evaluation based on the ISO 56002:2019 framework.

It is worth noting that among the reviewed studies, only one investigation, focused on Science and Technology (S&T) institutions [22], employed a multicriteria approach capable of analyzing cause-and-effect relationships and feedback mechanisms between primary-level standard clauses and their subordinate secondary-level items. However, despite employing an appropriate multicriteria decision-making methodology, this study did not incorporate fuzzy logic principles [24] to mitigate biased judgments and results in evaluating institutional innovation management system maturity.

Furthermore, the literature review encompassed an analysis of decision-making methodologies to inform the selection of optimal modeling approaches. Additionally, seminal works on organizational maturity models, as synthesized in [25], were examined to establish a comprehensive five-point maturity scale for integration into the conceptual framework.

3. RESEARCH AND DESIGN METHODOLOGY

To enhance clarity and avoid repetition, the methodological exposition was simplified and summarised. In addition, a schematic figure or summary table outlining all analytical steps has been added immediately after this section to provide readers with a concise overview of the process.

This section delineates the methodological framework designed to address the research questions articulated in Table 1. The investigation employs a systematic procedural model, adapted from Correia et al. [26], encompassing three distinct phases and five developmental stages that provide a comprehensive structural foundation for the research endeavor.

The methodological architecture comprises three sequential phases: (i) motivation, which establishes the theoretical and practical imperatives driving the research, (ii) development, which encompasses the systematic construction and refinement of the proposed framework, and (iii) validation, which subjects the framework to empirical scrutiny through rigorous testing and evaluation protocols.

The first two stages involved a comprehensive literature review and documentary analysis of scientific articles and normative documents published between 2008 and 2023, as mentioned in Section 2.

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	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] 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]
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 other organizations	What are the primary challenges faced by Light SESA, and what recommendations should be implemented to enhance outcomes and impacts derived from the value generated by its successful RD&I projects? [Section 5] 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]

Subsequently, the 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) [27] and Importance Performance Analysis (IPA) [28], were chosen in the fourth stage.

The Analytic Network Process is a decision-making method used to analyze complex systems with interdependent relationships. This allows the researcher to model and evaluate the interactions among different system elements, considering their direct and indirect impacts on each other.

The reason for selecting the ANP method from various multicriteria methods was primarily the comprehensive nature of the ISO 56002:2019 framework, 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, which represents the influence of network elements on each other through adjusted relative importance weights.

According to Saaty [27], 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 the 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.

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 [27].

Table 2. Saaty's nine-point scale [27].

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

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 the AHP method) 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 [27].

The third step in constructing the ANP model involves calculating the limit matrix and prioritizing the network elements. The limit matrix was obtained by increasing the weighted supermatrix to successive powers. In this study, 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 that corresponded to the aforementioned clauses.

The weights of the 28 items were calculated with the support of the Super Decisions® software [28]. 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) [29] is employed in the final 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 to assess the importance of various factors or criteria, and their corresponding performance, in identifying priorities for action. Regarding the proposed model, the use of IPA aims to efficiently allocate resources to improve the maturity level of the innovation management system of a given established company.

4. CONCEPTUAL MODEL BASED ON THE ISO 56002:2019 FRAMEWORK

In accordance with the methodological framework delineated in Section 3, the assessment model encompasses eight discrete stages, each of which is systematically elaborated and comprehensively explicated in the subsequent subsections, to ensure thorough understanding of the analytical process and its implementation protocols.

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

The analytical structure was established and built upon the 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.

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

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

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**

presence or absence of influence between factors. The matrix is organized with the 28 assessment factors grouped into seven clusters [27].

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 [27]. 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

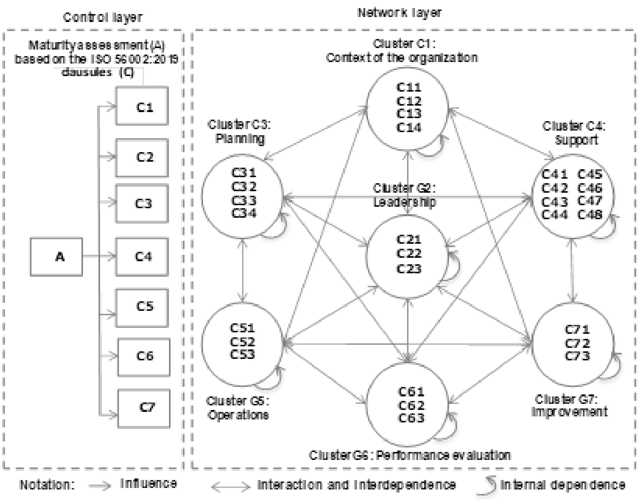

Figure 1. The network analytical structure based on the ISO 56002:2019 framework [8].

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

Maturity Level	Scale	Description
Nothing or informal	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.

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: Assigning weights to 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 [28], the weights of the 28 assessment factors are calculated, as described before.

4.5. Stage 5: Designing the maturity scale for assessing the innovation management system at the organizational level

A specially designed five-point maturity scale for evaluating the maturity of an innovation management system at the organizational level was proposed in [22], based on the common characteristics identified from various maturity models [25]. The maturity scale presented in Table 4 should be adopted in this stage.

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 [24] should be employed to compute the collective judgements, thereby promoting unbiased decisions. Nevertheless, robust evidence requires systematic record-keeping, traceability, and, where appropriate, internal or external expert audits to support the credibility of 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 the 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, the use of fuzzy logic is recommended.

The foundation of fuzzy logic [24] 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 can be generated from the results for each of the seven assessment dimensions, following the ISO 56004:2020 recommendations [29]. These charts provide a visual representation of the company's maturity levels across different aspects of innovation management.

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 the establishment of targets and action plans for enhancing the maturity level of a company's innovation management system, using the IPA method [30]. 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 [30].

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 8: 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 [31], an innovative company from the Brazilian electricity sector, 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 4, initially, we obtained the hierarchical control matrix

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
Optimized	5	4	5	5

(7 × 7) and the interfactorial dominance matrix (28 × 28), referring to the 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 [28].

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 [32].

Table 6. Final weights to the assessment factors.

Clauses and items of the Standard	Weights obtained by SD	Normalized weights per clause	Final weights
1. Context of the organization	0.240	1.000	0.25*
1.1 Understanding the organization and its context	0.087	0.363	1.45
1.2 Understanding the needs and expectations of interested parties	0.063	0.263	1.05
1.3 Determining the scope of the innovation management system	0.044	0.183	0.73
1.4 Establishing the innovation management system	0.046	0.192	0.77
2. Leadership	0.240	1.000	0.33*
2.1 Leadership and commitment	0.141	0.588	1.76
2.2 Innovation policy	0.034	0.142	0.42
2.3 Organizational roles, responsibilities and authorities	0.066	0.275	0.82
3. Planning	0.161	1.000	0.25*
3.1 Actions to address opportunities and risks	0.068	0.422	1.68
3.2 Innovation objectives and planning to achieve them	0.039	0.242	0.96
3.3 Organizational structures	0.034	0.211	0.84
3.4 Innovation portfolios	0.021	0.130	0.52
4. Support	0.149	1.000	0.13*
4.1 Resources	0.029	0.195	1.56
4.2 Competence	0.030	0.201	1.61
4.3 Awareness	0.015	0.101	0.81
4.4 Communication	0.006	0.040	0.32
4.5 Documented information	0.007	0.047	0.38
4.6 Tools and methods	0.008	0.054	0.43
4.7 Strategic intelligence management	0.041	0.275	2.20
4.8 Intellectual property management	0.013	0.087	0.70
5. Operations	0.101	1.000	0.33*
5.1 Organizational planning and control	0.024	0.238	0.71
5.2 Innovation initiatives	0.046	0.455	1.37
5.3 Innovation processes	0.031	0.307	0.92
6. Performance evaluation	0.064	1.000	0.33*
6.1 Monitoring, measurement, analysis and evaluation	0.029	0.453	1.36
6.2 Internal audit	0.004	0.063	0.19
6.3 Management review	0.031	0.484	1.45
7. Improvement	0.044	1.000	0.33*
7.1 General	0.015	0.341	1.05
7.2 Deviation, non-conformity and corrective action	0.012	0.273	0.84
7.3 Continual improvement	0.016	0.364	1.12

Note: (*) Equally important value = obtained by dividing 1.0 by the number N of items per clause.

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

After completing all the paired comparisons, as described in section 4.4, the Super Decisions® software (SD) was utilized to calculate the weights of the 28 assessment factors. The final weights and corresponding calculations are shown in Table 6.

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 in section 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 section 4.8, IPA matrices were built to chart decision-making zones concerning each assessment dimension, which will enable the establishment of targets and action plans for enhancing the maturity level of Light SESA's innovation management system.

6. DISCUSSION

The discussion of the results indicates that the proposed model demonstrated practical applicability and usefulness. The single-case application at Light SESA should be viewed as an empirical pathway, rather than a full validation of robustness. Future studies with standardised measurements, comparative references, and multiple organisations are recommended to establish formal validation at scale.

The study presents significant contributions by innovatively integrating the ISO 56002:2019 framework with advanced quantitative methods—the ANP method and fuzzy logic—offering a systematic and structured approach to assessing innovation management maturity. The empirical validation in a company from the Brazilian electricity sector strengthens the model's credibility, while the use of IPA matrices provides a practical tool for identifying decision zones and prioritizing actions.

However, certain limitations must be considered. The application in a single empirical case, although detailed and rigorous, may limit the generalization of results. The specific focus on the electric sector also suggests the need for additional validations in other industrial contexts. Additionally, the inherent complexity in implementing the ANP method may present a challenge for organizations with lower maturity in quantitative methods.

Compared to previous studies, the model presents notable advances. Unlike Santos et al.'s work [22], which also used the ANP method but was restricted to S&T institutions, this study incorporates fuzzy logic to minimize biases in assessments. The work also stands out in relation to Van Than and Hiep's research with Vietnamese companies [23], by offering a more structured and quantitative framework for evaluation. From the perspective of metrology, the model builds upon measurement principles and systematic evaluation protocols that are highly relevant to IMEKO's audience. However, it should be emphasised that the model does not constitute an auditing tool for conformity assessment or certification purposes under the ISO 56002:2019 standard. By linking decision-making structures with maturity assessment metrics derived from the ISO 56002:2019 framework, the model enhances both the credibility and the replicability of innovation maturity assessments across different industrial sectors.

The practical and theoretical implications of the study are substantial. For managers and professionals, the model provides a structured tool to evaluate and enhance innovation management systems, enabling objective identification of priority areas for improvement. From an academic perspective, the study contributes to the literature by demonstrating the viability and benefits of integrating quantitative methods with ISO 56002:2019 assessment.

The developed model establishes a foundation for future research in innovation management. Its application is recommended across different industrial sectors and organizational contexts, as well as conducting longitudinal studies to evaluate its effectiveness in continuous improvement of innovation management systems. The incorporation of other quantitative methods and model adaptation for different organizational sizes also represent promising research opportunities.

The successful experience at Light SESA suggests that the model can be particularly valuable for organizations seeking systematic and objective assessment of their innovation management systems. The combination of quantitative methods with the ISO 56002:2019 structure offers a balance between methodological rigor and practical applicability, contributing to the advancement of both theory and practice in innovation management.

7. CONCLUSIONS

This study developed and validated an assessment model for innovation management systems based on the ISO 56002:2019 standard, integrating multicriteria decision method (ANP) and fuzzy logic with IPA matrices. The three initial research questions were satisfactorily answered through the development and empirical application of the model.

The first question about how to assess the maturity level of innovation management systems was answered through the proposed analytical framework, which incorporated the seven dimensions and 28 assessment factors from ISO 56002:2019.

The second question related to relevant dimensions and factors was addressed by the comprehensive hierarchical structure developed.

Finally, the third question about integrating decision methods was answered by the successful implementation of the ANP method with fuzzy logic and IPA matrices.

The proposed model contributes significantly to the research field of innovation management by filling an important gap in the systematic assessment of innovation management systems. The innovative integration between the ISO 56002:2019 standard, the ANP method, fuzzy logic, and IPA matrices offers a quantitative approach, overcoming the limitations of previous studies that lacked structured methodologies.

The empirical validation at Light SESA demonstrated the model's practical applicability, resulting in an overall maturity assessment of 3.2 on a 5-point scale. The use of IPA matrices enabled the objective identification of priority areas for improvement.

Future research can expand the model's application to different industrial sectors and organizational contexts, conduct longitudinal studies, and explore the incorporation of other quantitative methods.

It is recommended that organizations interested in assessing their innovation management systems consider implementing the proposed model, adapting it as needed to their sectoral and organizational specificities. The developed framework provides a solid foundation for the systematic development of organizational innovation capability.

AUTHORS' CONTRIBUTION

Conceptualization, F. V. G., M. F. L. A; Methodology, F. V. G., M. F. L. A; writing—original draft preparation, F. V. G.; writing—review and editing, M. F. L. A. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

The authors thank the Brazilian funding agencies Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for their financial support. This study was financed in part by CAPES - Finance Code 001001.

REFERENCES

[1] M. C. Idris, A. Durmuşoğlu, A strategic roadmap for innovation management standards: An empirical investigation in Turkish manufacturing industry, Sustainability vol. 13 (2021) no. 15, article ID 8151.
DOI: 10.3390/su13158151

[2] J. Hyland, M. Karlsson, Towards a management system standard for innovation, J. Innov. Manag. vol. 9 (2021) no. 1, pp. XI-XIX. DOI: 10.24840/2183-0606_009.001_0002
[3] H. J. Harrington, F. Voehl, The Innovation Systems Cycle: Simplifying and Incorporating the Guidelines of the ISO 56002 Standard and Best Practices. Boca Raton, FL, USA: CRC Press, 2019. ISBN: 978-0367682668.
[4] J. Tidd, A review and critical assessment of the ISO 56002 innovation management systems standard: Evidence and limitations, Int. J. Innov. Manag. vol. 25 (2021) no. 1, article ID 2150049.
DOI: 10.1142/S1363919621500493
[5] L. Morel, C. Johan, Innovation management: a new serious game aligned with ISO 56002: 2019 – innovation management system, DS 110, in Proc. 23rd Int. Conf. Engineering and Product Design Education (E&PDE), 2021, pp. 1-6.
DOI: 10.35199/EPDE.2021.93
[6] S. B. Silva, Improving the firm innovation capacity through the adoption of standardized innovation management systems: a comparative analysis of the ISO 56002:2019 with the literature on firm innovation capacity, Int. J. Innov., vol. 9 (2021), no. 2, pp. 389-413.
DOI: 10.5585/iji.v9i2.19273
[7] European Committee for Standardization, CEN-TS 16555-1:2013 Innovation Management: Innovation Management System, Brussels: European Committee for Standardization, 2013.
[8] International Organization for Standardization, ISO 56002:2019. Innovation Management — Innovation Management System — Guidance, Geneva: ISO, 2019.
[9] T. Canas, J. S. Gomes, Management of research, development and innovation systems and the new NP 4457 Standard: An implementation case study, Proc. OpenRoads Conf., 2008, pp. 330–338.
[10] E. Pellicer, V. Yepes, C. Correa, G. Martínez, Enhancing R&D&i through standardization and certification: the case of the Spanish construction industry, Rev. Ing. Constr. vol. 23 (2008) no. 2, pp. 112–121.
DOI: 10.4067/S0718-50732008000200006
[11] A. Y. T. Rojas, Desarrollo de un modelo de aplicación de la norma UNE 166002 sobre implantación de sistemas de innovación en las PYMIS venezolanas, Ph.D. dissertation, Univ. Politécnica Madrid, Madrid, Spain, 2009. [in Spanish]
[12] P. N. P. F. Pimentel, Implementação de um sistema de gestão da investigação, desenvolvimento e inovação de acordo com a norma np 4457, M.Sc. thesis, Instituto Superior de Engenharia de Lisboa, Lisbon, Portugal, 2010. [in Portuguese]
[13] R. G. González, Metodología para la evaluación de la madurez del Sistema de gestión de la I+D+I en las organizaciones de acuerdo a las normas UNE 166002 e ISO/IEC 15504, M.Sc. thesis, Univ. Oviedo, Oviedo, Spain, 2012. [in Spanish]
[14] E. Pellicer, C. L. Correa, V. Yepes, L. F. Alarcón, Organizational improvement through standardization of the innovation process in construction firms, Eng. Manag. J. vol. 24 (2012) no. 2, pp. 40–53.
DOI: 10.1080/10429247.2012.11431935
[15] S. J. O. Cantú, A. R. P. Zapata, A. S. Alcántar, Análisis Exploratorio del Sistema de Gestión de la Tecnología, Según la Norma Mexicana NMX-GT-003-IMNC, Proc. XV Congreso Latino Iberoamericano de Gestión de la Tecnología, Porto, 2013. [in Spanish]
[16] S. D. P. Gomes, Estratégia e implementação da certificação de sistemas de gestão de investigação, desenvolvimento e inovação (NP 4457) em empresas em Portugal, M.Sc. thesis, Politécnico do Porto, Porto, Portugal, 2013. [in Portuguese]
[17] J. F. Guedes, Abordagem aos efeitos decorrentes da adopção de modelos de gestão da inovação normalizados, Working Papers Series, CIGEST, 2013. [in Portuguese]
[18] D. A. Josef, S. Al-Swiri, S. Rahman, The new standard for innovation management systems - A comparative study of Volvo Construction Equipment's innovation management system and CEN/TS standardized innovation management system, M.S. thesis, KTH Royal Institute of Technology, Stockholm, Sweden, 2015.
[19] M. Mir, M. Casadesús, Standardisation of innovation management: Implications for the adequacy of product development process, Innovar vol. 21 (2011) no. 40, pp. 171–187.
[20] G. Garechana, R. Río-Belver, I. Bildosola, M. R. Salvador, Effects of innovation management system standardization on firms: evidence from text mining annual reports, Scientometrics vol. 111 (2017) no. 1, pp. 1987–1996.
DOI: 10.1007/s11192-017-2345-7
[21] G. Santos, S. Gomes, V. Braga, A. Braga, V. Lima, P. Teixeira, J. C. Sá, Value creation through quality and innovation – a case study on Portugal, TQM J. vol. 31 (2019) no. 6, pp. 928–947.
DOI: 10.1108/TQM-12-2018-0223
[22] M. C. B. Santos, M. F. L. Almeida, Self-Assessment Model based on the ISO 56002:2019 Standard for Evaluating Innovation Management Systems of Science and Technology Institutions, in Proc. 2022 IEEE ICE/ITMC & IAMOT Joint Conf., Nancy, France, 2022, pp. 1–8.
[23] N. Van Thanh, H. M. Hiep, Investigating factors affecting innovation management in Vietnam's enterprises based on innovation management standard ISO 56002, Int. J. Innov. Learn. vol. 33 (2023) no. 4, pp. 393–407.
[24] L. A. Zadeh, Fuzzy Sets, Information and Control vol. 8 (1965) no. 3, pp. 338–353.
DOI: 10.1016/S0019-9958(65)90241-X
[25] R. Jochem, D. Geers, P. Heinze, Maturity measurement of knowledge-intensive business processes, TQM J. vol. 23 (2011) no. 4, pp. 377–387.
DOI: 10.1108/17542731111139464
[26] E. Correia, R. Calili, J. F. Pessanha, M. F. Almeida, Definition of regulatory targets for electricity non-technical losses: proposition of an automatic model-selection technique for panel data regressions. Energies vol. 16 (2023) no. 6, p. 2519.
DOI: 10.3390/en16062519
[27] T. L. Saaty, M. Takizawa, Dependence and independence: From linear hierarchies to nonlinear networks, Eur. J. Oper. Res. vol. 26 (1986) no. 2, pp. 229–237.
DOI: 10.1016/0377-2217(86)90184-0
[28] Creative Decision Foundation, Super Decisions V.3.2 Manual, 2019. Online [Accessed 1 Nov 2024]
https://www.superdecisions.com/manuals/
[29] International Organization for Standardization, ISO 56004:2020. Innovation Management Assessment — Guidance, Geneva: ISO, 2020.
[30] N. Slack, The importance-performance matrix as a determinant of improvement priority, Int. J. Oper. Prod. Man. vol. 14 (1994) no. 5, pp. 59–75.
DOI: 10.1108/01443579410056803
Light SESA, Institutional page of Light SESA, 2023. Online [Accessed 1 Nov 2024]
http://ri.light.com.br/en/light/history-and-company-profile/
[31] F. V. Gomes, Self-assessment model based on the ABNT NBR ISO 56002:2020 Standard for evaluating the innovation management system of organizations, M.Sc. dissertation, Graduate Program in Metrology, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil, 2021.