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IMAX-AI: AN EXPLAINABLE ARTIFICIAL INTELLIGENCE DECISION SUPPORT SYSTEM FOR INNOVATION MATURITY ANALYTICS IN HIGHER EDUCATION

IMAX-AI: UM SISTEMA DE APOIO À DECISÃO BASEADO EM INTELIGÊNCIA ARTIFICIAL EXPLICÁVEL PARA ANÁLISE DA MATURIDADE DA INOVAÇÃO NO ENSINO SUPERIOR

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Resumo

Os modelos de maturidade da inovação no ensino superior normalmente fornecem avaliações quantitativas, mas carecem de capacidades interpretativas inteligentes para apoiar a tomada de decisão estratégica. Este estudo apresenta o IMAX-AI, um artefato de apoio à decisão baseado em Inteligência Artificial Explicável (Explainable Artificial Intelligence – XAI), desenvolvido para ampliar o Índice de Maturidade da Inovação para Universidades (IM-IU). Fundamentado na abordagem Design Science Research, o IMAX-AI integra validação psicométrica, ponderação de indicadores baseada em Random Forest e uma camada interpretativa de IA explicável em uma arquitetura de quatro camadas composta por aquisição de dados, análise quantitativa da maturidade, inteligência explicável e visualização orientada à governança. O artefato foi demonstrado empiricamente por meio de sua aplicação em uma universidade pública da região Sul do Brasil, evidenciando sua capacidade de identificar perfis multidimensionais de maturidade, detectar assimetrias estruturais entre as dimensões institucionais e gerar recomendações transparentes e priorizadas para apoiar a governança universitária. Ao combinar avaliação multidimensional da maturidade, aprendizado de máquina interpretável e suporte inteligente à decisão, o IMAX-AI amplia a análise da maturidade da inovação para além do benchmarking estático, promovendo uma governança institucional explicável, baseada em evidências e orientada ao aperfeiçoamento contínuo das instituições de ensino superior.

Palavras-chave: Inteligência artificial explicável; Maturidade da inovação; Sistemas de apoio à decisão.

Abstract

Innovation maturity models in higher education typically provide quantitative assessments without offering intelligent interpretive capabilities to support strategic decision-making. This study introduces IMAX-AI, an explainable artificial intelligence–driven decision-support artifact designed to extend the validated Innovation Maturity Index for Universities (IM-IU). Developed following a Design Science Research approach, IMAX-AI integrates psychometric validation, Random Forest–

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based feature weighting, and an explainable AI interpretive layer within a four-layer enterprise information systems architecture comprising data acquisition, quantitative maturity analytics, explainable intelligence, and governance-oriented visualization. The artifact was empirically demonstrated through its application in a public university located in Southern Brazil, illustrating its ability to identify multidimensional maturity profiles, detect structural asymmetries across institutional dimensions, and generate transparent, prioritized governance recommendations. By combining multidimensional maturity assessment with interpretable machine learning and intelligent decision support, IMAX-AI advances innovation maturity analytics beyond static benchmarking toward explainable, evidence-based governance for higher education institutions.

Keywords: Explainable artificial intelligence; Innovation maturity; Decision support systems.

1 Introduction

Universities play a central role in national and regional innovation systems, functioning as knowledge generators and coordinators within increasingly complex socio-economic environments (Etzkowitz; Leydesdorff, 2000; OECD, 2012). In this context, innovation maturity has emerged as a critical construct for understanding how higher education institutions structurally embed innovative practices across governance, culture, internationalization, sustainability, and ecosystem engagement (Guerrero *et al*., 2024; Schaap *et al*., 2025).

The Innovation Maturity Index for Universities (IM-IU) was recently developed as a multidimensional and empirically validated framework integrating psychometric validation and computational weighting techniques to assess the institutional capacity for innovation within higher education institutions. The model incorporates seven interrelated dimensions—Institutional Creativity, Internationalization, Organizational Culture for Innovation, Integration of Teaching, Research and Extension, Academic Transformation, Sustainability and Social Responsibility, and Innovation Ecosystem—capturing both structural and cultural determinants of institutional innovation maturity.

Although the IM-IU combines Exploratory Factor Analysis and Random Forest Importance to provide statistically robust maturity classifications, it primarily operates as a structured measurement framework. Similar to other maturity models (Saihi *et al*., 2024; Tocto-Cano *et al*., 2025), it delivers benchmarking and diagnostic outputs but does not incorporate an intelligent interpretive layer capable of identifying cross-dimensional asymmetries, strategic leverage points, or institutional misalignments. Importantly, the proposed maturity perspective is not associated with technological product maturity models, such as Technology Readiness Levels (TRLs), but rather with the organizational and governance-related maturity of universities in fostering innovation capabilities.

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Within enterprise information systems research, decision-makers increasingly demand intelligent analytics rather than static indicators. Artificial intelligence (AI), particularly explainable machine learning approaches, has demonstrated significant potential in enhancing decision support systems by providing transparent reasoning, predictive insights, and strategic prioritization (Granstrand; Holgersson, 2020; Zamir *et al*., 2025).

To address this limitation, this study proposes IMAX-AI, an explainable artificial intelligence-based decision support system designed to extend the IM-IU into an intelligent interpretive framework. By integrating psychometric validation, Random Forest weighting, and an explainable AI interpretive layer, the proposed system advances innovation maturity analytics from descriptive measurement toward intelligent governance support within higher education institutions. Thus, the focus of IMAX-AI is the assessment and interpretation of institutional innovation maturity, enabling universities to identify organizational strengths, structural asymmetries, and strategic priorities for innovation-oriented governance and continuous institutional development.

2 Theoretical Backgroup

2.1 Innovation Maturity Assessment in Higher Education

Innovation in higher education institutions is increasingly conceptualized as a multidimensional and systemic process embedded within governance, organizational culture, international collaboration, sustainability practices, and ecosystem integration (Etzkowitz; Leydesdorff, 2000; Guerrero *et al*., 2024; Schaap *et al*., 2025). Traditional performance-based metrics—such as publication counts, patents, or funding volumes—fail to capture the structural and cultural determinants of institutional innovation maturity (Halász, 2018; Philpott *et al*., 2011).

To address these limitations, multidimensional maturity frameworks have been proposed to evaluate the degree to which innovation is institutionalized across organizational domains (Saihi et al., 2024; Tocto-Cano et al., 2025). The Innovation Maturity Index for Universities (IM-IU) represents an empirically validated model integrating psychometric validation and Random Forest-based weighting to assess institutional innovation capacity. The model encompasses seven interdependent dimensions that collectively reflect structural readiness and cultural adaptability for innovation.

Despite methodological robustness, maturity models generally remain diagnostic tools. They provide structured measurement and benchmarking but lack interpretive intelligence capable of dynamically explaining interdependencies or generating strategic guidance.

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2.2 Decision Support Systems and Machine Learning in Governance

Decision Support Systems (DSS) are designed to assist managerial decision-making through data processing, analytical modeling, and interactive visualization. In enterprise information systems research, DSS architectures have evolved from rule-based systems toward machine learning-driven analytical engines capable of identifying patterns in multidimensional datasets.

Machine learning methods, particularly ensemble models such as Random Forest, are widely recognized for their robustness in handling nonlinear relationships and complex feature interactions. In the context of innovation analytics, Random Forest techniques have been applied to determine variable importance and optimize predictive accuracy. However, predictive performance alone is insufficient for governance contexts that demand transparency and interpretability.

The increasing adoption of AI in organizational decision environments has therefore emphasized the development of Explainable Artificial Intelligence (EAI). Explainability enhances trust, transparency, and accountability by clarifying how model outputs are generated. Techniques such as feature importance analysis and model-agnostic explanation methods enable decision-makers to understand which variables influence outcomes and why.

Within higher education governance, where strategic decisions affect institutional missions, sustainability policies, and international positioning, the interpretability of AI-driven insights becomes essential.

2.3 Explainable AI for Governance Analytics

Explainable AI extends traditional machine learning by incorporating interpretive mechanisms that translate statistical outputs into understandable insights. In innovation ecosystems characterized by multidimensional interactions (Granstrand; Holgersson, 2020), explainability supports the identification of structural imbalances and strategic leverage points.

By integrating feature importance analysis with maturity dimensions, AI-driven systems can detect asymmetries across institutional domains, highlight priority intervention areas, and generate structured strategic recommendations. This interpretive capability transforms maturity assessment from a descriptive benchmarking instrument into an intelligent governance analytics tool.

Building upon these theoretical foundations, this study proposes IMAX-AI as a hybrid system combining psychometric validation, machine learning weighting, and explainable interpretive intelligence to support strategic innovation governance in higher education institutions.

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3 System Architecture – IMAX-AI

This section presents the architecture of IMAX-AI, an explainable artificial intelligence decision support system designed to interpret innovation maturity results and generate governance-oriented insights. The system extends the Innovation Maturity Index for Universities (IM-IU) by adding an AI interpretive layer on top of the psychometric and computational components already established in the original framework.

3.1 Architectural Overview

IMAX-AI adopts a four-layer architecture that integrates psychometric validation, machine learning, explainable artificial intelligence, and decision-support functionalities within a unified enterprise information systems framework. The architecture enables end-to-end processing, from data acquisition and maturity assessment to the generation of governance-oriented recommendations.

The first layer, Data Acquisition and Preprocessing, processes Likert-scale responses (1–5) collected from university managers according to the maturity anchors defined in the IM-IU framework. Preprocessing includes data consistency verification, missing-value treatment, normalization procedures, and mapping of indicators to the seven validated dimensions, producing a structured indicator matrix for subsequent analyses.

The second layer, Random Forest-Based Feature Weighting, computes the relative importance of dimensions and indicators using machine learning techniques, generating the weights required for maturity computation.

The third layer, the IMAX Quantitative Maturity Engine, calculates normalized weighted scores, dimension-level maturity indexes, overall institutional maturity, and multidimensional maturity profiles.

The fourth layer, Explainable AI–Driven Decision Support, transforms quantitative outputs into interpretable governance intelligence by integrating profile detection, feature attribution, gap analysis, and a strategic recommendation engine. The resulting outputs are presented through governance-oriented visualizations that support institutional planning and evidence-based decision-making.

The modular architecture ensures transparency, traceability, scalability, and replicability while maintaining compatibility with enterprise information systems adopted by higher education institutions.

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3.2 Layer 1 – Data Acquisition and Preprocessing

The input layer processes Likert-scale responses (1–5) collected from university managers according to the maturity anchors defined in the IM-IU framework. Data preprocessing includes consistency validation, missing-value treatment, normalization procedures, and indicator mapping to the seven validated dimensions. The output of this layer is a structured indicator matrix aligned with the validated dimensional structure.

3.3 Layer 2 – IMAX Quantitative Engine

This layer operationalizes the maturity computation pipeline established in the IM-IU model. It comprises three components: (i) the validated psychometric structure, (ii) Random Forest-based feature weighting to compute indicator importance, and (iii) normalized weighted scoring to derive dimension-level and global maturity indexes. The output is a quantitative maturity profile including dimension scores, global classification, and indicator-level contributions.

3.4 Layer 3 – Explainable AI Interpretive Layer

The interpretive layer represents the primary innovation of IMAX-AI. It transforms quantitative outputs into explainable governance intelligence through three integrated modules:

• Profile Detection, identifying institutional maturity patterns using clustering over multidimensional maturity vectors.

• Explainability Module, generating global and local interpretability outputs based on Random Forest feature importance, dimension-level gap analysis, and rule-based explanatory logic.

• Strategic Recommendation Engine, combining rule-based logic with AI-assisted natural language generation to produce prioritized governance actions aligned with institutional maturity asymmetries and strategic improvement opportunities.

The explainability strategy adopted in IMAX-AI emphasizes transparency and traceability between indicators, feature importance, maturity scores, and generated recommendations, enabling interpretable governance analytics. Although model-agnostic explainability techniques such as SHAP (SHapley Additive exPlanations) and LIME (Local Interpretable Model-Agnostic Explanations) were not formally implemented in the current version, the proposed architecture is compatible with their future integration to enhance local interpretability and granular institutional diagnostics.

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This layer transforms maturity assessment from a descriptive measurement framework into a governance-oriented actionable intelligence system

3.5 Layer 4 – Decision Support Interface

The final layer delivers results through a governance-oriented dashboard supporting institutional, campus, and unit-level decision-making. Outputs include maturity heatmaps, driver rankings, prioritized action cards, and longitudinal monitoring capabilities.

3.6 System Traceability

IMAX-AI ensures transparency by maintaining traceability between observed indicators, Random Forest weights, maturity scores, and generated recommendations. This transparency-by-design approach strengthens interpretability and governance reliability.

4 Method

This section presents the architecture of IMAX-AI, an explainable artificial intelligence decision support system designed to interpret innovation maturity results and generate governance-oriented insights. The system extends the Innovation Maturity Index for Universities (IM-IU) by adding an AI interpretive layer on top of the psychometric and computational components already established in the original framework.

4.1 Research Design

This study adopts a design science research approach, focusing on the development and evaluation of an intelligent decision support artifact (IMAX-AI). The research objective is to extend the validated IM-IU maturity model into an explainable AI-driven governance system. The methodological process comprises system design, implementation, and empirical evaluation using institutional maturity data.

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4.2 Data Collection and Study Context

Data were collected in two stages consistent with the IM-IU development pipeline. First, an expert panel (n = 32) assessed the conceptual clarity, representativeness, and relevance of the proposed indicators and dimensions, providing the basis for psychometric validation.

Second, the validated instrument was administered to university managers using a 5-point Likert scale anchored from 1 = Nonexistent to 5 = Excellence, capturing the perceived implementation level of innovation practices across the institution.

One private higher education institutional case was analyzed to demonstrate the end-to-end operation of IMAX-AI, enabling the computation of institutional innovation maturity indexes and the generation of explainable governance outputs.

4.3 Case Study

The proposed IMAX-AI framework was contextualized in a large public university located in Southern Brazil. Founded in the second half of the twentieth century, the institution has established itself as one of the country's leading higher education and research universities, offering a broad portfolio of undergraduate and graduate programs across multiple fields of knowledge. It maintains a strong commitment to teaching, research, extension, and innovation, supported by a robust academic infrastructure that includes research centers, graduate programs, technology transfer initiatives, innovation laboratories, entrepreneurship programs, and collaborative partnerships with industry, government, and society. The university also plays a strategic role in regional and national innovation ecosystems through its participation in scientific networks, technology-based entrepreneurship initiatives, and sustainable development projects. These institutional characteristics provide an appropriate organizational context for illustrating the applicability of the proposed IMAX-AI architecture in supporting innovation maturity assessment and governance-oriented decision-making within higher education institutions.

4.4 Measures and Variables

The measurement model comprises seven dimensions (Institutional Creativity, Internationalization, Organizational Culture for Innovation, Integration of Teaching-Research-Extension, Academic Transformation, Sustainability and Social Responsibility, and Innovation Ecosystem) and their respective indicators, as defined and validated in the IM-IU framework.

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The dependent variable used for feature weighting was the global maturity level, while independent variables corresponded to the validated indicators, following the Random Forest Importance procedure adopted in the original model.

4.5 Data Processing and System Execution

Preprocessing included consistency checks, handling of missing values, and indicator-to-dimension mapping. The psychometric structure was examined through Exploratory Factor Analysis using adequacy criteria (KMO and Bartlett's test), and internal consistency was assessed with Cronbach's alpha, adopting established thresholds.

Next, Random Forest regression was trained with 5-fold cross-validation and bootstrapping to derive indicator and dimension weights. Weighted scores were computed by normalizing indicator values and applying the derived weights, producing dimension-level and global maturity indexes.

Finally, the explainable AI layer generated: (i) maturity profiles; (ii) driver rankings and gap analysis; and (iii) prioritized strategic recommendations, delivered through a decision-support dashboard (Figure 1). Maturity classification follows the predefined index ranges established in the IM-IU framework. Table 1 presents the maturity levels and their interpretative descriptions.

Table 1 - Innovation Maturity Levels and Interpretation

Maturity Level	IM-IU Range	
Initial	0.000–0.200	The university exhibits incipient innovation practices, with isolated and uncoordinated initiatives.
Basic	0.201–0.400	The university has basic structured processes for innovation, though with limited strategic alignment and low integration among teaching, research, and extension.
Intermediate	0.401–0.600	The university presents a consolidated and evolving structure, with formal innovation policies, external partnerships, and regular innovation and entrepreneurship initiatives.
Advanced	0.601–0.800	Innovation is integrated into institutional governance, with robust and consistent performance in innovation practices, technology transfer, and ecosystem engagement.
Highly consolidated	0.801–1.000	The university serves as a benchmark or reference in innovation, demonstrating consolidated policies, a pervasive innovation culture, and measurable regional, national, or international impact.

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5 Results

5.1 Psychometric and Weighting Results

In Table 2 the psychometric validation confirmed the robustness of the seven-dimensional structure of the IM-IU. KMO values ranged from 0.774 to 0.911 and Bartlett's test of sphericity was significant ($p < 0.001$), supporting factor adequacy. Cronbach's alpha coefficients varied between 0.796 and 0.934, indicating strong internal consistency.

Table 2 - Cronbach's alpha, Kaiser-Meyer-Olkin index, Bartlett's test of sphericity, communalities, and factor loadings according to academic experts' assessments (n = 32)

Dimension indicator	Evaluation statistics					
	CA	TVE	KMO	BTS	Minimum - Maximum	
					COM	FL
Institutional creativity	0.864	50.607	0.785	< 0.001		
IC.01 – IC.08					0.601 – 0.809	0.639 – 0.906
Internationalization	0.882	50.150	0.774	< 0.001		
INT.01 – INT.08					0.449 - 0.805	0.630 – 0.850
Integration of teaching, research, and extension	0.826	49.501	0.792	< 0.001		
TRE.01 – TRE.08					0.709 – 0.780	0.608 – 0.830
Organizational culture for innovation	0.934	65.438	0.911	< 0.001		
OCI.01 - OCI.08					0.536 – 0.825	0.670 - 0.879
Innovation ecosystem	0.796	48.206	0.805	< 0.001		
IE.01 – IE.08					0.414 – 0.647	0.612 – 0.787
Academic transformation	0.878	49.414	0.809	0.000		
AT.01 – AT.08					0.456 – 0.817	0.644 – 0.836
Sustainability and social responsibility	0.886	50.098	0.838	0.000		
SSR.01 – SSR.08					0.449 - 0.697	0.636 – 0.802

CA = Cronbach's alpha; TVE = total variance explained; KMO = Kaiser-Meyer-Olkin; BTS = Bartlett's test of sphericity; COM = communality; FL = factor loading; IC = institutional creativity; INT = internationalization; TRE = teaching, research, and extension; OCI = organizational culture for innovation; IE = innovation ecosystem; AT = academic transformation; SSR = sustainability and social responsibility

In Table 3, the Random Forest Importance analysis generated a clear hierarchy among dimensions. Institutional Creativity (IC) emerged as the most influential dimension (0.2263),

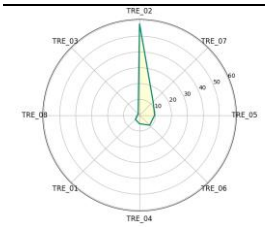
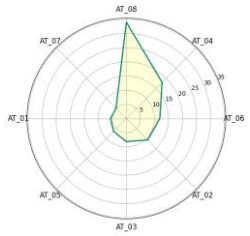
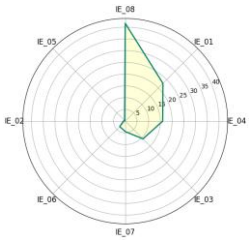
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followed by Internationalization (0.1809) and Organizational Culture for Innovation (0.1514). These results indicate that institutional innovation maturity is structurally driven by creativity mechanisms, international engagement, and enabling organizational culture, reinforcing the systemic nature of innovation governance.

Table 3 - Relative importance and global weights of dimensions and indicators derived from the random forest importance method (cross-validation process)

Dimension	Indicator	Degree of importance		Global indicator weight
		Dimension	indicator	
Institutional creativity		0.2263		
	IC.08		0.2767	0.0626
	IC.06		0.2316	0.0524
	IC.03		0.2160	0.0489
	IC.05		0.1931	0.0437
	IC.02		0.0422	0.0096
	IC.04		0.0212	0.0048
	IC.07		0.0180	0.0041
	IC.01		0.0011	0.0002
Internationalization		0.1809		
	INT.08		0.2719	0.0615
	INT.04		0.2242	0.0507
	INT.06		0.1841	0.0417
	INT.07		0.1710	0.0387
	INT.01		0.0758	0.0171
	INT.02		0.0491	0.0111
	INT.05		0.0145	0.0033
	INT.03		0.0095	0.0021
Organizational culture for innovation		0.1514		
	OCI.07		0.2952	0.0447
	OCI.08		0.1964	0.0297
	OCI.04		0.1854	0.0281
	OCI.03		0.1762	0.0267
	OCI.05		0.1077	0.0163
	OCI.06		0.0197	0.0030
	OCI.02		0.0142	0.0022
	OCI.01		0.0053	0.0008
Integration of teaching, research, and extension		0.1485		
	TRE.02		0.5781	0.0858
	TRE.07		0.1201	0.0178
	TRE.05		0.0947	0.0141

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	TRE.06		0.0895	0.0133
	TRE.04		0.0542	0.0080
	TRE.01		0.0374	0.0055
	TRE.08		0.0138	0.0021
	TRE.03		0.0123	0.0018
Academic transformation		0.1169		
	AT.08		0.3394	0.0397
	AT.04		0.1800	0.0210
	AT.06		0.1191	0.0139
	AT.02		0.1071	0.0125
	AT.03		0.0814	0.0095
	AT.05		0.0644	0.0075
	AT.01		0.0566	0.0066
	AT.07		0.0520	0.0061
Sustainability and social responsibility		0.0848		
	SSR.01		0.2367	0.0201
	SSR.08		0.1994	0.0169
	SSR.02		0.1919	0.0163
	SSR.06		0.1245	0.0106
	SSR.04		0.0684	0.0058
	SSR.05		0.0674	0.0057
	SSR.03		0.0654	0.0055
	SSR.07		0.0464	0.0039
Innovation ecosystem		0.0794		
	IE.08		0.4164	0.0331
	IE.01		0.2273	0.0181
	IE.04		0.1598	0.0127
	IE.03		0.1069	0.0085
	IE.07		0.0444	0.0035
	IE.06		0.0333	0.0026
	IE.02		0.0080	0.0006
	IE.05		0.0040	0.0003

5.2 Empirical Maturity Profiles - Case 1

Case 1 represents a public university located in Southern Brazil. The institution has operated for several decades and offers a broad range of undergraduate and postgraduate programs across multiple fields of knowledge. It maintains established activities in teaching, research, extension, innovation, and technology transfer, as well as collaborations with government, industry, and society.

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The university also plays a relevant role in regional and national innovation ecosystems through research networks, entrepreneurship initiatives, institutional innovation structures, and projects related to sustainable development. Due to ethical and confidentiality considerations, the institution's identity is not disclosed. As shown in Table 4, the results across the IM-IU dimensions provide a multidimensional assessment of its innovation maturity profile, highlighting both consolidated institutional capabilities and areas requiring further strategic development.

Table 4 - Results by dimension for Case 1.

Evaluated dimension	Score	IM-IU level	Interpretive summary
Institutional creativity	0.4896	Intermediate	The university has established initiatives that encourage creativity and innovation; however, more structured institutional mechanisms are needed to systematically foster innovative practices among faculty, students, and staff.
Internationalization	0.5328	Intermediate	International collaborations and partnerships are well established, although their integration into the university's innovation strategy remains uneven and could be further strengthened.
Organizational culture for innovation	0.4559	Intermediate	The institution recognizes the strategic importance of innovation, but the innovation culture is not yet consistently disseminated across all academic and administrative units.
Integration of teaching, research, and extension	0.4965	Intermediate	Teaching, research, and extension activities are integrated through selected interdisciplinary initiatives; however, broader institutional coordination is required to enhance synergy across these core missions.
Academic transformation	0.5075	Intermediate	The university demonstrates ongoing academic transformation through innovative teaching practices and digital initiatives, although these efforts remain concentrated in specific programs and units.
Sustainability and social responsibility	0.2078	Basic	Sustainability and social responsibility initiatives are present but remain fragmented. A more comprehensive institutional strategy aligned with governance and the Sustainable Development Goals would strengthen this dimension.
Innovation ecosystem	0.4341	Intermediate	The university actively participates in regional innovation networks and external partnerships,

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			although stronger coordination among innovation actors would enhance ecosystem integration and institutional impact.
Overall	0.4626	Intermediate	The university demonstrates an intermediate level of innovation maturity, characterized by consolidated institutional capabilities alongside opportunities to strengthen governance, sustainability, and the integration of innovation practices across the institution.

6 Discussion

IMAX-AI extends the multidimensional understanding of innovation maturity in higher education institutions by operationalizing maturity assessment within an intelligent governance architecture. Innovation in universities has long been conceptualized as a systemic and ecosystem-driven phenomenon embedded in university–industry–government interactions (Etzkowitz & Leydesdorff, 2000) and broader innovation ecosystems (Granstrand & Holgersson, 2020). However, existing assessment approaches remain predominantly descriptive, providing benchmarking information without intelligent mechanisms capable of supporting evidence-based governance and strategic decision-making.

Existing maturity assessment frameworks emphasize structural readiness and institutional innovation capacity (Halász, 2018; Saihi *et al*., 2024; Tocto-Cano *et al*., 2025), while recent literature highlights the strategic challenges entrepreneurial universities face in aligning governance, research excellence, sustainability, and innovation ecosystems (Guerrero *et al*., 2024; Schaap *et al*., 2025). Although these models provide structured evaluation mechanisms, they generally lack analytical capabilities that explain relationships among dimensions, identify structural asymmetries, or prioritize strategic interventions.

The empirical application illustrates that institutional innovation maturity is inherently multidimensional. The analyzed public university achieved an overall **intermediate** level of innovation maturity; however, considerable variability was observed across dimensions, particularly in Sustainability and Social Responsibility compared with the remaining organizational capabilities. These findings demonstrate that aggregated maturity indices may conceal important structural differences among institutional domains, reinforcing the importance of explainable analytical approaches capable of identifying governance priorities and supporting targeted institutional improvement.

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Unlike traditional maturity models, IMAX-AI does not merely classify institutions into predefined maturity levels. Instead, it integrates psychometric validation, machine learning–based feature weighting, quantitative maturity assessment, and explainable artificial intelligence within a unified decision-support architecture. The incorporation of Random Forest feature importance enables the identification of high-impact institutional drivers, while the explainable layer translates quantitative outputs into interpretable governance recommendations, supporting more informed and transparent decision-making.

From an Enterprise Information Systems perspective, IMAX-AI represents an evolution from conventional maturity assessment tools toward an intelligent decision-support artifact capable of integrating data acquisition, analytical processing, explainable reasoning, and governance-oriented visualization within a single architecture. This integration responds to the growing demand for intelligent enterprise systems that not only process organizational data but also generate transparent, interpretable, and actionable knowledge for institutional governance (Zamir *et al*., 2025).

Overall, IMAX-AI contributes by bridging innovation maturity modeling, explainable artificial intelligence, machine learning, and intelligent analytics into a governance-oriented decision-support system. The proposed architecture advances maturity assessment beyond descriptive benchmarking, enabling higher education institutions to transform multidimensional innovation data into transparent, evidence-based, and strategically actionable governance intelligence.

7 Conclusion

This study introduced IMAX-AI, an explainable artificial intelligence–driven decision-support system designed to extend the validated Innovation Maturity Index for Universities (IM-IU) into an integrated governance intelligence architecture. Rather than assessing the technological maturity of products or technologies, IMAX-AI evaluates the institutional capacity for innovation by combining organizational, managerial, strategic, and ecosystem-related dimensions within a unified analytical framework.

The empirical application demonstrated that institutions exhibiting similar overall maturity levels may present substantial differences across individual dimensions. In particular, the results highlighted that institutional innovation maturity should be interpreted as a multidimensional construct, where aggregated scores alone may overlook critical organizational strengths and weaknesses. By incorporating machine learning–based feature weighting and explainable analytics, IMAX-AI enables decision-makers to identify high-impact institutional drivers and prioritize strategic interventions with greater transparency and precision.

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The principal theoretical contribution of this study lies in integrating innovation maturity assessment with explainable artificial intelligence within a unified governance framework. Methodologically, the study proposes a reproducible four-layer architecture that combines psychometric validation, Random Forest feature weighting, quantitative maturity computation, and explainable decision-support mechanisms. From a practical perspective, IMAX-AI provides universities with an intelligent governance tool capable of transforming multidimensional maturity assessments into interpretable recommendations, thereby supporting institutional planning, resource allocation, and continuous improvement.

From an Enterprise Information Systems perspective, the proposed artifact demonstrates how artificial intelligence can be embedded into organizational assessment systems to enhance transparency, interpretability, and strategic decision-making. The modular architecture facilitates scalability, integration with institutional dashboards, and future incorporation of real-time organizational data, reinforcing its applicability within digital governance environments.

This study has some limitations. The empirical evaluation was conducted using a single public university located in Southern Brazil, which limits the generalizability of the findings to other institutional contexts. Furthermore, the explainable recommendation engine is currently based on predefined interpretive rules combined with machine-learning outputs, and therefore may benefit from more advanced adaptive reasoning mechanisms in future versions.

Future research should validate IMAX-AI across diverse national and international higher education systems, explore longitudinal applications for monitoring institutional innovation maturity over time, and integrate real-time institutional data streams. Additional developments may incorporate advanced explainable AI techniques, predictive maturity forecasting, and large language model–based recommendation engines to further enhance governance support.

Beyond higher education, the proposed architecture is sufficiently flexible to be adapted to other organizational domains requiring multidimensional maturity assessment and explainable governance analytics. Consequently, IMAX-AI contributes to the evolution of intelligent Enterprise Information Systems by demonstrating how psychometric measurement, machine learning, explainable artificial intelligence, and decision-support capabilities can be integrated into a single governance-oriented analytical framework.

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