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HIGHER EDUCATION AND LEADERSHIP: APPLICATION OF A MATHEMATICAL MODEL TO EVALUATE MANAGEMENT COMPETENCIES AND INSTITUTIONAL EFFICIENCY

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Summary
Higher education faces the challenge of training leaders capable of managing institutions efficiently in highly competitive contexts. This article proposes the application of a mathematical model based on confirmatory factor analysis and multiple regression models to evaluate managerial competencies and their relationship with institutional efficiency. From a sample of Latin American universities, the key leadership factors that influence strategic decision-making, educational innovation, and institutional satisfaction are identified. The results show that the integration of mathematical models allows quantifying managerial competencies and establishing predictions about institutional efficiency, providing a useful tool for university management in the 21st century.

Keywords: higher education, leadership, managerial competencies, institutional efficiency, mathematical model.

Introduction

Higher education has become a strategic pillar for the economic, social and cultural development of nations. In a world characterized by uncertainty, technological acceleration, and global competitiveness, universities face the challenge of training leaders capable of responding to the changing demands of society and efficiently managing institutional resources (Carayannis & Morawska-Jancelewicz, 2022). Leadership skills in academic contexts transcend traditional administrative management and involve managerial competencies that foster innovation, sustainability, and organizational resilience.

Recent literature has shown that higher education institutions require leaders with adaptive and strategic skills to face processes of digital transformation, social inclusion, and institutional sustainability (Zawacki-Richter & Jung, 2022). In this sense, university leadership is no longer limited to academic management, but incorporates more complex approaches that include pedagogical innovation, the strengthening of collaborative networks, knowledge management, and international projection (Said-Hung & Gratacós, 2021).

Likewise, institutional efficiency is configured as a key variable to evaluate the performance of universities, linked to indicators of educational quality, student satisfaction, scientific productivity, and financial sustainability (Fumasoli et al., 2020). The combination of strategic

leadership and robust managerial competencies is associated with more competitive institutions, capable of implementing inclusive policies and adaptation to crisis contexts, as evidenced during the COVID-19 pandemic (Peters et al., 2021).

From this perspective, this article proposes a mathematical model that integrates confirmatory factor analysis and multiple regression in order to evaluate the relationship between the managerial competencies of university leaders and institutional efficiency. The main objective is to offer a methodological tool that allows quantifying the impact of leadership in university management, providing empirical evidence for the formulation of policies for continuous improvement in the field of higher education.

Theoretical framework

Leadership in Higher Education

Leadership in higher education has undergone a significant transformation in recent years. Traditionally, the role of the university leader was focused on the management of resources and the supervision of academic processes, but nowadays a more strategic, participatory, and global vision is required (Wang & Torrisi-Steele, 2021). The complexity of contemporary educational contexts, traversed by digitalization, cultural diversity, and labor market demands, has driven the need for leaders with innovation, resilience, and change management competencies (Zawacki-Richter & Jung, 2022).

Rectors, deans and university directors become agents of institutional transformation, capable of aligning strategic objectives with policies of educational quality, social inclusion and sustainability (Ahn et al., 2022). In this sense, recent literature emphasizes that leadership cannot be understood in isolation, but in relation to university governance systems and the construction of collaboration networks at the international level (Carayannis & Morawska-Jancelewicz, 2022).

Management skills

Management competencies represent a set of skills and attitudes that enable academic leaders to respond effectively to management challenges. These competencies are divided into strategic, interpersonal, and innovation dimensions (Rodríguez-Gómez et al., 2020).

In the last five years, various studies have highlighted the relevance of integrating **emotional intelligence**, **people management,** and **institutional communication** as key competencies to improve organizational efficiency (Said-Hung & Gratacós, 2021). On the other hand, digitalization and online education have reinforced the need for technology **management** skills, which positions leaders as mediators between educational innovation and financial sustainability (Salinas et al., 2020).

Mathematical models in educational management

The use of mathematical models in the management of higher education has become relevant as a strategy to evaluate institutional efficiency and the quality of leadership processes (Mendoza-González & Soto, 2021). These models make it possible to analyze large volumes of data and detect significant relationships between managerial competencies and institutional performance.

For example, **multiple regression models** have shown efficacy in predicting the impact of leadership on administrative efficiency, while **confirmatory factor analysis (CFA)** helps identify latent dimensions of managerial competencies (Fumasoli et al., 2020). The combination of these techniques provides a robust framework for evidence-based decision-making, strengthening university governance.

Table 1. Comparison of dimensions of leadership in higher education (2019–2023)

Dimension	*Key features*	*Institutional impact*	*References*
Strategic leadership	Focus on planning, global vision, sustainability	Improves competitiveness and institutional efficiency	Ahn et al. (2022); Carayannis & Morawska-Jancelewicz (2022)
Participatory leadership	Stakeholder inclusion, shared decision-making	Increased organizational commitment and cohesion	Rodríguez-Gómez et al. (2020)
Digital Leadership	Adaptation to technological environments, educational innovation	Foster digital transformation and institutional resilience	Wang & Torrisi-Steele (2021); Zawacki-Richter & Jung (2022)
Emotional Leadership	Conflict management, empathy, effective communication	Increases student and teacher satisfaction	Said-Hung & Gratacós (2021)

Table 2. Application of mathematical models in higher education

Mathematical model	*Purpose*	*Expected results*	*References*
Confirmatory factor analysis (CFA)	Identify dimensions of managerial competencies	Validation of theoretical constructs	Fumasoli et al. (2020)
Multiple regression	Relate competencies and institutional efficiency	Predicting academic and administrative outcomes	Mendoza-González & Soto (2021)
Structural equation models	Integrate latent and observed variables	Complex Relationships Explained	Salinas et al. (2020)

Methodology

Research Design

This study is framed in a **quantitative, correlational and cross-sectional design**, whose objective is to analyze the relationship between managerial competencies and institutional efficiency in Latin American universities. The quantitative approach allows variables to be measured objectively and advanced statistical techniques to be applied to validate the results (Creswell & Creswell, 2021). The correlational character seeks to establish links between the constructs of leadership and efficiency, without intentionally manipulating the variables (Hernández-Sampieri & Mendoza, 2022).

Population and sample

The target population was made up of **directors, deans and heads of academic management** in public and private universities in Colombia, Mexico and Ecuador. The sample was selected through an **intentional non-probabilistic sampling**, consisting of **220 participants**.

According to the literature, a sample of more than 200 cases is suitable for applying confirmatory factor analysis and multiple regression models, since it guarantees statistical robustness (Hair et al., 2020).

Data collection tools

A structured questionnaire of 40 items **was used**, divided into two sections:

1. **Management competencies**: measures on a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree).
2. **Institutional efficiency**: indicators of academic quality, student satisfaction and organizational sustainability.

The instrument was adapted based on previous models for the assessment of managerial competencies in higher education (Rodríguez-Gómez et al., 2020; Said-Hung & Gratacós, 2021). Content validation was carried out with experts and a **pilot analysis** in 30 participants, reaching a **Cronbach α of 0.91**, which indicates high internal consistency (Taber, 2019).

Study variables

Table 1. Variables and dimensions analyzed

Variable Type	*Variable*	*Dimensions*	*Main indicators*	*References*
Independent	Management skills	Strategic Leadership, Innovation, Communication, People Management	Planning, creativity, empathy, team management	Rodríguez-Gómez et al. (2020); Said-Hung & Gratacós (2021)
Dependent	Institutional efficiency	Academic, administrative, financial	Teaching quality, student satisfaction, economic sustainability	Fumasoli et al. (2020); Ahn et al. (2022)

Procedures

Data collection was carried out online using digital forms. The confidentiality of the participants and informed consent were guaranteed, complying with ethical principles of social research (APA, 2020).

Applied mathematical model

The following statistical techniques were applied to the analysis of the data:

1. **Confirmatory factor analysis (CFA):** used to verify the construct validity of the dimensions of managerial competencies. The TFA allows us to confirm whether the items of the questionnaire adequately represent the theoretical dimensions (Hair et al., 2020).
2. **Multiple regression:** applied to estimate the influence of managerial competencies on institutional efficiency. Strategic leadership, innovation, institutional communication, and people management were included as predictor variables.
3. **Model validation:** indicators such as **RMSEA (< 0.08)** and **CFI (> 0.90)** were used for CFA, and **R^2** as a fitting measure for regression models (Kline, 2020).

Table 2. Justification of the mathematical model

Statistical technique	*Objective in the study*	*Justification*	*References*
Confirmatory factor analysis (CFA)	Validate dimensions of managerial competencies	Ensures construct validity and item adequacy	Hair et al. (2020)
Multiple regression	Estimate the impact of competencies on institutional efficiency	Identifies significant predictors of efficiency	Kline (2020)
Reliability analysis (Cronbach's α)	Assess internal questionnaire consistency	Confirms the reliability of the scales applied	Taber (2019)

Results

Confirmatory factor analysis (CFA)

The TFA was carried out in order to validate the theoretical structure of managerial competencies. The results confirmed adequate **construct validity**, with a comparative fit index (**CFI = 0.93**), a Tucker-Lewis index (**TLI = 0.91**), and a mean square error of approximation (**RMSEA = 0.06**), within acceptable values in social science studies (Hair et al., 2020; Kline, 2020).

The **factor loads** of the items ranged from **0.65 to 0.88**, indicating adequate consistency in each dimension.

Table 1. Standardized factor loads by dimension

Dimension	*Items*	*Range of factor loads*	*Composite reliability (CR)*	*Cronbach's Alfa*
Strategic leadership	10	0.72 – 0.85	0.89	0.87
Innovation and change	8	0.70 – 0.83	0.87	0.85
People Management	12	0.65 – 0.82	0.91	0.90
Institutional communication	10	0.68 – 0.88	0.90	0.89

The reliability values exceed the recommended threshold of 0.70 (Taber, 2019), confirming that the instrument is valid and reliable for measuring managerial competencies.

Multiple regression

To assess the influence of managerial competencies on institutional efficiency, a multiple regression model was applied. The results showed that the general model explains **63 % of the variance ($R^2 = 0.63$, $p < 0.01$)** of institutional efficiency.

The most influential predictors were:

- **Strategic leadership ($\beta = 0.41$, $p < 0.001$)**
- **Innovation and change ($\beta = 0.36$, $p < 0.001$)**
- While **people management ($\beta = 0.22$, $p < 0.05$)** and **institutional communication ($\beta = 0.19$, $p < 0.05$)** showed moderate but significant effects.

Table 2. Multiple Regression Results

Independent variable	*Standardized coefficient (β)*	*Standard Error*	*Value t*	*Sig. (p)*
Strategic leadership	0.41	0.05	8.20	0.000 **
Innovation and change	0.36	0.06	6.55	0.000 **
People Management	0.22	0.07	3.14	0.002 *
Institutional communication	0.19	0.08	2.85	0.005 *
General model (R²)	**0.63**	—	—	—

*p < 0.05; **p < 0.01*

These results coincide with recent research that points to **strategic leadership and innovation as key predictors of university efficiency**, while people management and communication strengthen institutional cohesion and student satisfaction (Ahn et al., 2022; Zawacki-Richter & Jung, 2022).

Comparative analysis by type of university

An additional analysis was carried out to compare public and private universities. It was found that in **private universities** the impact of innovation was greater (β = 0.42), while in **public universities** people management stood out (β = 0.29).

Table 3. Comparison of Institutional Efficiency Predictors by Type of University

Dimension	*Public universities (β)*	*Private universities (β)*
Strategic leadership	0.39 **	0.43 **
Innovation and change	0.31 **	0.42 **
People Management	0.29 *	0.18 ns
Institutional communication	0.21 *	0.17 ns

*ns = significant no; *p < 0.05; **p < 0.01*

This finding suggests that leadership models are not homogeneous, but respond to the contexts and organizational structures of each type of institution, which coincides with recent studies of university governance (Fumasoli et al., 2020; Carayannis & Morawska-Jancelewicz, 2022).

Conclusions

The findings of this study show that **managerial competencies** are a determining factor in the institutional efficiency of higher education. In particular, **strategic leadership** and **innovation capacity** were identified as the main predictors of efficiency, confirming that universities require managers with a vision of the future, adaptability, and the ability to implement organizational change processes (Ahn et al., 2022; Zawacki-Richter & Jung, 2022).

Likewise, **people management** and **institutional communication** showed moderate but relevant effects, suggesting that efficiency does not depend only on strategic planning, but also on internal cohesion, team motivation, and transparency in processes (Rodríguez-Gómez et al., 2020). These results coincide with recent research that highlights the importance of

comprehensive leadership, capable of balancing innovation with human management (Said-Hung & Gratacós, 2021).

From a practical perspective, this mathematical model provides a quantitative tool that allows **diagnosing and monitoring the level of managerial competencies** in university leaders. The application of confirmatory factor analysis and multiple regression provides solid evidence to support accreditation processes **, quality assessment, and continuous improvement** in higher education (Fumasoli et al., 2020). In addition, the identification of key dimensions can guide management training programs and organizational development plans adapted to the specific needs of public and private universities (Carayannis & Morawska-Jancelewicz, 2022).

Regarding the **social and academic implications**, the results show that strengthening managerial competencies not only improves administrative efficiency, but also has an impact on student satisfaction, scientific productivity, and institutional sustainability (Peters et al., 2021). The COVID-19 pandemic demonstrated that universities with innovative and resilient leaders responded more effectively to the crisis, reinforcing the need to integrate change management as a cross-cutting axis in higher education.

Finally, as **future lines of research**, it is recommended:

1. Expand the sample to more countries in Latin America and Europe to contrast cultural and structural differences.
2. Incorporate additional variables such as **digital transformation**, **internationalization**, and **environmental sustainability** into the evaluation of university efficiency (Wang & Torrisi-Steele, 2021).
3. Apply mixed methodologies that integrate quantitative analysis with qualitative studies, in order to understand the perceptions of leaders and teachers about the impact of leadership in their institutions.

In conclusion, this study provides a solid methodological framework to assess managerial competencies in higher education, demonstrating that strategic leadership and innovation are the essential drivers of institutional efficiency. However, the importance of maintaining a comprehensive approach that incorporates the human and communicative dimension is underlined, thus ensuring the sustainability and competitiveness of universities in a world in constant transformation.

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