Revista Colombiana de Educación N. 101 Año 2026
ISSN 0120-3916 / e-ISSN: 2323-0134
DOI: https://doi.org/10.17227/rce.num101-21202
Universidad Pedagógica Nacional, Colombia

MICMAC Structural Analysis in Virtual Industrial Engineering Program to Identify Strategic Variables

Received: February 28, 2024
Evaluated: Jun 4, 2024
Published: July 1, 2026

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Type: Research article

Abstract

This study focuses on identifying the strategic variables that influence the educational quality of the virtual Industrial Engineering program at a higher education institution in southeast Mexico. A non-probabilistic convenience sampling method was used, involving twelve professors and three managers from the academic sub-direction, the academic development department, and the Industrial Engineering department. Structural analysis from prospective studies was applied using MICMAC software. After identifying and categorizing factors, a matrix of cross-impacts was created, culminating in the identification and analysis of strategic variables. The results revealed eight strategic variables located in the conflict zone, characterized by high mobility and independence. These variables emerged as priority issues requiring attention to improve the program's educational quality. This study provides a detailed view of the key areas that need to be addressed to optimize the educational process and ensure student success in the field of Industrial Engineering. The findings will also support the development of strategic plans to prevent student dropout, academic conflict, and course repetition within the virtual Industrial Engineering program—critical factors for maintaining enrollment and enhancing educational quality.

Keywords

higher education; distance education; non-traditional education; decision making; educational quality

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Análise estrutural MICMAC no curso virtual de Engenharia Industrial para identificação de variáveis estratégicas

Resumo

Este estudo tem como foco a identificação das variáveis estratégicas que influenciam a qualidade educacional do curso virtual de Engenharia de Produção em uma instituição de ensino superior no sudeste do México. Utilizou-se uma amostragem não probabilística por conveniência, envolvendo doze professores e três gestores das áreas de subdireção acadêmica, desenvolvimento acadêmico e departamento de Engenharia de Produção. A análise estrutural dos estudos prospectivos foi aplicada por meio do software MICMAC. Após a identificação e categorização dos fatores, elaborou-se uma matriz de impactos cruzados, culminando na identificação e análise das variáveis estratégicas. Os resultados revelaram oito variáveis estratégicas localizadas na zona de conflito, caracterizadas por alta mobilidade e independência. Essas variáveis surgem como questões prioritárias que demandam atenção para melhorar a qualidade educacional do curso. O estudo fornece uma visão detalhada das áreas-chave que precisam ser trabalhadas para otimizar o processo educacional e assegurar o sucesso dos estudantes no campo da Engenharia de Produção. Os achados também apoiarão o desenvolvimento de planos estratégicos para prevenir evasão estudantil, conflitos acadêmicos e repetência — fatores críticos para manter a matrícula e elevar a qualidade educacional.

Palavras-chave

educação superior; educação a distância; educação não tradicional; tomada de decisão; qualidade educacional

Análisis estructural MICMAC en el programa virtual de Ingeniería Industrial para identificar variables estratégicas

Resumen

Este estudio se centra en la identificación de las variables estratégicas que influyen en la calidad educativa del programa virtual de Ingeniería Industrial en una institución de educación superior del sureste de México. Se empleó un muestreo no probabilístico por conveniencia, con la participación de doce docentes y tres directivos de la subdirección académica, el departamento de desarrollo académico y el departamento de Ingeniería Industrial. Se aplicó el análisis estructural de los estudios prospectivos mediante el software MICMAC. Tras la identificación y categorización de los factores, se elaboró una matriz de impactos cruzados que culminó en la identificación y análisis de las variables estratégicas. Los resultados revelaron ocho variables estratégicas ubicadas en la zona de conflicto, caracterizadas por alta movilidad e independencia. Estas variables surgieron como cuestiones prioritarias que requieren atención para mejorar la calidad educativa del programa. El estudio ofrece una visión detallada de las áreas clave que deben ser abordadas para optimizar el proceso educativo y garantizar el éxito de los estudiantes en el campo de la Ingeniería Industrial. Los hallazgos también respaldarán la elaboración de planes estratégicos orientados a prevenir la deserción estudiantil, los conflictos académicos y la repetición de cursos, factores críticos para mantener la matrícula y fortalecer la calidad educativa.

Palabras clave

educación superior; educación a distancia; educación no tradicional; toma de decisiones; calidad educativa

To cite this article:

García-Reyes, D. A., García-Ramírez, M. T. & Eliseo-Dantés, H. (2026). MICMAC Structural Analysis in Virtual Industrial Engineering Program to Identify Strategic Variables. *Revista Colombiana de Educación*, (101), e21202, https://doi.org//10.17227/rce.num101-21202

Introduction

Nowadays, quality assessment is a fundamental consideration for any institution, requiring exhaustive analysis and rigorous evaluation of the quality of the products or services it offers. This approach aims to meet the expectations of its customers or users (Soto, 2022). Therefore, in the field of education, institutions must ensure the improvement of quality, as it represents substantial growth in the individual and collective development of people, equipping them with skills and knowledge essential for holistic personal growth. Thus, educational quality is a crucial aspect in the evolution of education, especially in the context of virtual programs. As technology transforms how learning and teaching occur, it is critical to understand what quality truly means in this digital environment.

From a socio-formative perspective, Martínez-Iñiguez et al. (2020) mention that educational quality includes characteristics and conditions that ensure an educational system or institution complies with the standards and criteria established to guarantee an education of excellence. On the other hand, UNESCO (2005) mentions that educational quality comprises a set of factors that make the educational process efficient and effective, allowing students to achieve learning objectives satisfactorily and develop skills that enable them to participate fully in society.

In this sense, the quality of higher education should impact individuals' quality of life by providing access to better job opportunities, fostering stable economic growth, and offering tools to promote innovation and productivity. As mentioned by Lule, Serrano, and Montenegro (2023), quality education is a fundamental pillar for the progress of societies and the advancement of humanity.

Quality in higher education is crucial in various contemporary contexts, including political, cultural, economic, technological, and social spheres (Vega, 2020). Ensuring educational quality has become a priority for governmentss and educational authorities, as it serves as a foundation for socioeconomic, technological, and cultural development due to its influence on human capital formation (García, García & Lozano, 2020).

Educational quality at the higher education level is a complex and multifaceted challenge due to several interrelated factors. First, the diversity of educational institutions and programs makes it difficult to apply uniform standards, as each may have different objectives, pedagogical approaches, and resources (Rojas et al., 2023). In addition, rapidly evolving fields of study and technology require constant curriculum updates and faculty training, which can be costly and difficult to implement effectively. Inadequate funding can also limit institutions' ability to provide high-quality resources and services, negatively

affecting students' educational experience. Moreover, evaluation and quality assurance are complicated by a lack of robust evaluation systems and institutional resistance to change (Sotelo et al., 2022). Furthermore, globalization and increasing international competition require institutions to constantly strive to remain current and relevant in an increasingly diverse and competitive educational landscape. Therefore, ensuring educational quality at the higher education level requires a comprehensive approach that addresses a variety of institutional, financial, technological, and pedagogical challenges.

In the context of non-face-to-face modalities, evidencing and ensuring educational quality constitutes a significant challenge for higher education institutions, particularly in Mexico. According to Cervantes, Bañuelos, Chávez, and Rocha (2015), this challenge is attributed to the complexities of evaluation methodologies established by national agencies. These complexities include the lack of evaluation mechanisms specifically designed for virtual education, a problem originating from inconsistencies in the regulations and laws that shape this modality.

Morocho and Rama (2015), emphasize the need to update existing processes in distance education, as the instruments used are perceived as imprecise, lacking the capacity to demonstrate the outcomes of these innovative educational modalities. Rama (2015) argues that an educational evaluation system should cover all its dimensions, areas, and factors in the university environment, from management and implementation to the learning results, addressing this issue from its intricate nature.

In this sense, it is essential to consider evaluation systems capable of systematizing the large amount of data obtained during the process. Furthermore, it is crucial to recognize that the introduction of Information and Communication Technologies (ICT) in educational systems not only implies their incorporation but also demands reconfigurations in working methods, spaces, and educational functions, as Sagástegui (2018) argues. While the integration of ICT generates a large number of advantages in educational actors (Chávez, Martínez & Dávila, 2020), it can also present challenges in developing an optimal teaching-learning process (Molina & Rivera, 2019).

Although it may seem that good teaching practices alone would be enough for students to develop the necessary competencies, the problem goes beyond that. It extends to the infrastructure and administrative processes of institutions, involving students, teachers, administrative staff, and managers. Given this problem, there is a need to understand the context surrounding Higher Education Institutions and how they prepare themselves for environmental changes. Simultaneously, the factors involved play an important role in understanding and studying educational systems. Therefore, this study was carried out in a public

institution, particularly in one of its programs, starting from the question: What are the main factors that determine the educational quality in the virtual careers of Higher Education Institutions?

Methodology

The study adopted a mixed research approach due to its inherent characteristics it possesses, as mentioned by Guelmes and Nieto (2015), who explain that the mixed approach involves collecting, analyzing, and linking both quantitative and qualitative data within the same research. A non-probabilistic convenience sampling method was employed to select a specific group of experts in the field of virtual education and Industrial Engineering. The sample consisted of a total of twelve teachers and three managers, including representatives of the academic sub-directorate, the head of academic development, and the head of Industrial Engineering. These participants were selected based on their availability, experience in teaching virtual courses, and relevant knowledge in the study's subject area. This approach allowed for an in-depth exploration of the virtual Industrial Engineering program and helped identify key strategic variables.

The research was carried out in a Higher Education Institution in the public sector, located in southeast Mexico. As mentioned earlier, the academic faculty of the Industrial Engineering program and academic directors participated in the study. The structural analysis method was used for a prospective study, focusing on analyzing variables and factors, as well as their relationships within a system, to anticipate potential future scenarios. Additonally, the Method of Cross Impacts Multiplication Applied to Classification (MICMAC) software was used to identify and analyze the interactions and dependencies between different factors, classified into six variables within the virtual Industrial Engineering program. This enabled a deeper understanding of the dynamics, relationships, and their influence on the quality and effectiveness of the educational program.

Development

The structural method aims to qualitatively relate the factors of interest that are affecting a system or influencing a particular variable. Similarly, the method has the ability to interrelate these factors to measure their level of impact in the short, medium, and long term (Godet, 2007). One of the most relevant characteristics of structural analysis is that it relies on the subjective opinions of the experts involved in the study system. In summary, the method helps to "identify the main variables, both influential and dependent, as well as the essential variables for

the system's evolution" (Garza & Cortez, 2011, p. 336). Based on the above, the application of the method was developed through the following stages:

Identification and categorization of factors

In this first stage, ideas were gathered regarding significant internal and external factors for achieving educational quality in the virtual program. Through reflection and debate, the twelve professors and the three directors from the academic sub-directorate, the academic development department, and the Industrial Engineering department complied a preliminary list of 32 factors within the six variables of the context (social variable, cultural variable, technological variable, political variable, environmental variable, and economic variable). This list underwent a screening process, which resulted in 19 factors. It is important to point out that this process was carried out over several sessions, with collective work supported by the Microsoft Excel tool.

MICMAC cross-impact matrix

In this second stage, the experts completed the cross-impact matrix with the 40 factors previously selected, using the MICMAC software. The matrix was filled out collaboratively by all t experts in a qualitative manner, responding to the following question: What is the degree of influence of factor i in relation to factor j? Thus, subjectively, the group of experts assigned a weighting according to the following criteria, as described by Godet (2007): (0) No influence, (1) Weak influence, (2) Moderate influence, (3) Strong influence, and (P) Potential influence.

Identification and analysis of strategic factors

For the third phase, the MICMAC software processed the factors and interrelated them, positioning the results in a coordinate system on a Cartesian plane, divided into four categories, determined by the quadrants of the influence-dependence plane (Godet, 2010):

- Conflict zone (quadrant one): These factors are both highly influential and highly dependent on other factors within the system. They are considered as critical nodes, as they exert significant influence on the system.
- Power zone (quadrant two): These factors have a high influence on the system but are not highly dependent on other variables.

- Zone of autonomous variables (quadrant three): Variables that have a low influence on the system and also do not depend significantly on other variables.
- Output zone (quadrant four): These variables are highly influenced by other factors within the system but have a low influence on the overall system.

The positioning of the factors made it possible to visualize the importance of the 40 factors, revealing the degree of importance of each factor for the future. In the interpretation of the axes, motoricity (y-axis) refers to the impact thata factor exerts on the others, while dependence (x-axis) refers to the degree of subordination of a factor in relation to the others (Villegas, et al., 2020).

Results

With the objective of improving the educational quality of the Industrial Engineering program taught in virtual modality, the experts determined that, due to the conditions of the six variables of the context (social variable, cultural variable, technological variable, political variable, environmental variable, and economic variable) 29 factors of change currently have an impact, as listed in Table 1:

Table 1.
Factors affecting the quality of education

Factors			
1	Teacher-student relationship	**11**	Scholarships and student support
2	Teaching content	**12**	Tutoring and academic advising services
3	Teaching methods	**13**	Medical insurance
4	Adaptability in ICT	**14**	Psychological care
5	Internet connectivity	**15**	Attrition plan
6	Virtual library service	**16**	Repetition plan
7	Promotion of research	**17**	Underperformance plan
8	Internships, placements or visits in the employer's sector	**18**	School Conflict Plan
9	Agreements, integrations and business alliances	**19**	Government reforms
10	Monitoring student performance within the program		

Note: The factors presented in the table were determined by the Institution's experts.

As a result of the analysis and reflection of these factors, the MICMAC software was used for the cross-impact matrix, where, through the weighting explained

above, the degree of influence of each factor in relation to another was determined, resulting in the double-entry matrix shown in Figure 1:

	1 : Relac M-E	2 : Cont enseñ	3 : Met enseñ	4 : Dia y dis	5 : Promo inv	6 : Adap TIC	7 : Tut y ases	8 : Pra est vi	9 : Biblio vir	10 : Internet	11 : Becas est	12 : Seg medico	13 : Aten psico	14 : P desercio	15 : P repitien	16 : P bajo ren	17 : P conflict	18 : Refor gube	19 : Conv empre
1 : Relac M-E	0	2	2	2	2	2	3	3	3	3	3	2	1	2	3	2	3	2	3
2 : Cont enseñ	2	0	3	2	2	2	1	1	3	3	2	2	2	2	2	2	2	2	2
3 : Met enseñ	3	3	0	2	1	2	2	2	3	1	1	2	1	2	3	3	3	2	2
4 : Dia y dis	2	3	3	0	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2
5 : Promo inv	1	3	3	2	0	3	2	3	3	3	3	3	3	3	3	3	3	3	3
6 : Adap TIC	2	3	3	2	3	0	2	3	3	3	3	3	3	3	3	3	3	3	1
7 : Tut y ases	2	2	2	3	3	3	0	2	3	2	2	3	3	3	2	2	1	1	2
8 : Pra est vi	2	3	3	2	3	3	2	0	2	2	3	3	3	2	2	2	3	3	3
9 : Biblio vir	2	1	3	3	2	3	2	2	0	1	3	3	3	2	3	3	3	2	2
10 : Internet	2	2	2	2	1	2	3	2	3	0	3	3	3	2	3	3	3	3	2
11 : Becas est	2	2	1	2	3	3	2	1	1	2	0	2	2	2	2	2	3	2	2
12 : Seg medico	2	3	3	2	3	3	2	3	3	3	2	0	3	3	1	3	3	3	3
13 : Aten psico	1	2	3	2	3	3	2	3	2	3	3	3	0	2	2	2	2	2	3
14 : P desercio	2	2	2	3	2	2	3	3	3	3	2	2	2	0	3	3	3	3	2
15 : P repitien	2	3	3	3	3	2	3	3	3	2	3	2	3	3	0	2	2	2	2
16 : P bajo ren	3	3	2	3	1	2	2	3	2	2	2	3	2	3	2	0	2	2	3
17 : P conflict	3	3	3	3	3	2	3	3	3	3	2	2	3	2	3	2	0	2	2
18 : Refor gube	2	2	3	2	2	2	3	1	3	2	3	3	3	2	2	2	2	0	3
19 : Conv empre	2	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	2	1	0

Figure 1.
Cross-impact matrix with weights
Note: The double-entry matrix is obtained by applying the MICMAC analysis.

MICMAC analysis allows the identification of key areas within a system by categorizing variables according to their influence and dependence, allowing decision-makers to focus their efforts on strengthening the most relevant and strategic variables for the system in question. The MICMAC software provides the positioning of each of the variables in its corresponding zone on the map, based on the influence analysis. Figure 2 shows a map of influences and dependencies and how they are distributed in the quadrants:

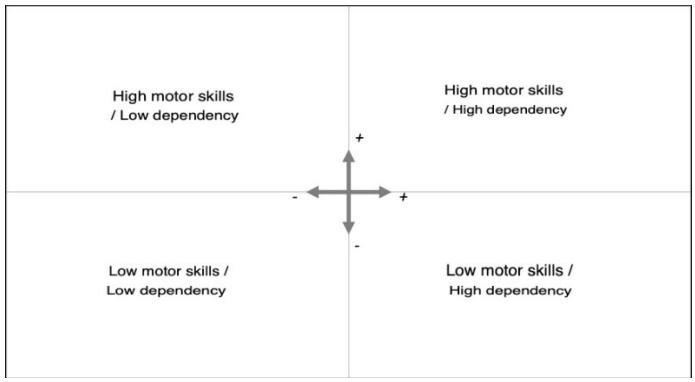


Figure 2.
Cartesian reference plane of motility and dependence

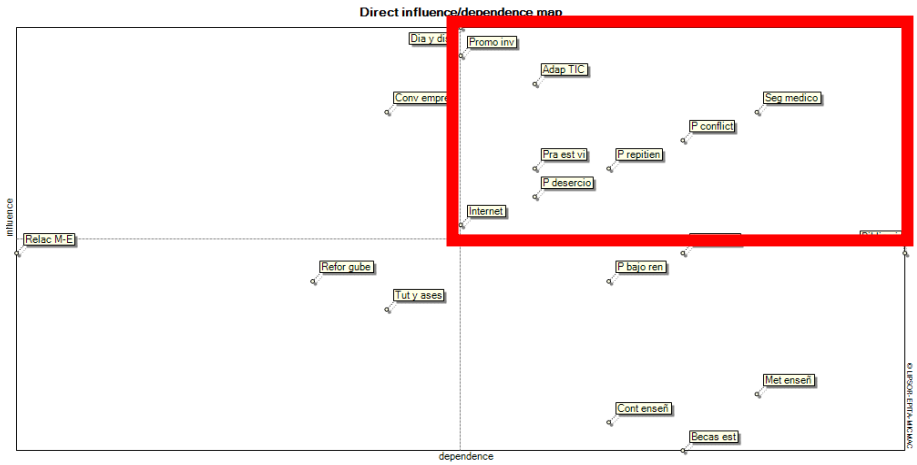
Table 2 shows the arrangement of the 19 strategic factors within the Cartesian plane of motoricity and dependence, according to their influence and relationship with each other. In quadrant I the factors with a high degree of motoricity and dependence can be observed, meaning they are highly influential on other factors and, in turn, , highly influenced by others. The factors with the greatest impact are those closest to the upper right corner of the plane, as shown in Figure 3:

Table 2.
Factors pertaining to the conflict zone

Factors		Description
11	Medical insurance	Coverage and financial protection in case of illness, injury or other health problems.
22	School Conflict Plan	A set of strategies and actions designed to prevent and address the problem of school conflict.
33	Repetition plan	Set of strategies and actions designed to prevent and address the problem of grade repetition.
44	Attrition plan	Set of strategies and actions designed to prevent and address the problem of dropout.
55	Internships, placements or visits in the employer's sector	These are educational activities in which students participate in practical and real experiences within organizations, companies or other entities of the working world.
66	Adaptability in ICT	It is the ability of individuals to adjust, learn and thrive in a constantly changing technological environment, specifically in the context of Information and Communication Technologies (ICT).
77	Promotion of research	It is the implementation of efforts and strategies aimed at fostering, supporting and improving research activity in an institution, community or specific field.
88	Internet connectivity	Refers to the institution's ability to provide Internet accessibility to all administrative staff, faculty and students.

Note: Conceptualization of the factors located in the conflict zone.

Figure 3.
Factors at the motor and dependency level



The application of prospective structural analysis, specifically using the MICMAC method, emerges as a valuable and strategic tool for improving educational quality. By decomposing and analyzing the various factors that influence the educational system, this approach allowed a deep understanding of the interactions and dependencies that directly impact the quality of education. The precise identification of these factors, their hierarchy and the evaluation of their interrelationships provide a solid basis for informed decision-making and the formulation of effective educational policies, as it will allow experts and, consequently, the actors in the context studied, to propose strategies for improvement.

The MICMAC methodology, by considering both influence and dependence among factors, allowed for a comprehensive view of the complexity inherent in the educational environment. The analysis facilitated the identification of critical areas requiring priority attention and, at the same time, revealed strategic opportunities to enhance academic performance and the learning experience. Through the results obtained, it was possible to reflect on the development of strategic plans to prevent dropout, school conflict, and course repetition among students of the virtual mode Industrial Engineering program, which are vital aspects for maintaining school enrollment and improving educational quality. Additionally, it was determined that medical insurance is an important factor for an integral quality service that should be offered to students. Due to the virtual modality, this service is not currently provided or promoted, making it a focus of attention for institutional administration.

Discussion

The results obtained through the MICMAC methodology revealed deep insights into the complexity of the educational environment, specifically within virtual modality Industrial Engineering programs. This methodology, by considering both influence and dependence among factors, allowed for the identification of critical areas that require priority attention, while simultaneously revealing strategic opportunities to improve academic performance and the learning experience.

From a theoretical perspective, these results align with existing literature on educational management and quality in higher education. For example, authors such as Farfán and Reyes (2017), Martínez-Iñiguez et al. (2020), and Álvarez et al. (2020) highlight the importance of a comprehensive and systemic vision in educational management to address the complex challenges faced by educational institutions today. The MICMAC methodology, by providing a tool to analyze the interrelationship of multiple factors, supports this approach and offers a structured way to address complexity in educational decision-making.

Additionally, the reflection on the development of strategic plans to reduce dropout, school conflict and repetition among virtual mode Industrial Engineering students is supported by the theory of student retention. Authors such as Jiménez, Hernández and Rodríguez (2021) and Buitrago (2020) have emphasized the importance of creating learning environments that foster student engagement and belonging, thereby reducing dropout rates and increasing student satisfaction.

The results of this study have important implications for educational practice and institutional management. First, the identification of critical areas and strategic opportunities provides a solid foundation for designing and implementing interventions aimed at improving educational quality and the student experience in virtual Industrial Engineering programs.

Moreover, the lack of promotion and provision of health insurance for virtual modality students highlights the need for a review of institutional policies to ensure comprehensive and equitable service for all students. This finding emphasizes the importance of considering the specific needs and circumstances of students in virtual environments and adapting institutional services accordingly.

Conclusions

The application of the MICMAC prospective structural analysis in improving educational quality not only strengthened decision-making but also fostered teamwork, reflection, innovation, and effectiveness in the design and

implementation of educational strategies. By empowering educational institutions with detailed information and forward-looking perspectives, the foundations were laid for a stronger, more resilient education system focused on continuous learning, providing opportunities for more equitable and sustainable educational development.

Educational quality is revealed as an integral and multifaceted concept that transcends the work of teachers and administrators within an institution. While their commitment and leadership are fundamental elements, recognizing the complexity of educational quality involves understanding the interconnection of various factors. Students, as key actors in the educational process, play a crucial role by actively contributing to the academic dynamics and the development of a collaborative learning environment. Therefore, it is expected that this research will continue, including the opinions and perspective of the student body.

By recognizing that continuous improvement depends not only on the efforts of educators and leaders but also on the active participation of students and the consideration of multiple factors, a solid foundation is established for promoting a high-quality educational environment. This holistic approach, encompassing all relevant actors and aspects, leads to more effective strategies for raising educational quality and preparing students for the challenges of an ever-changing world. Educational quality, in its holistic essence, thus becomes a collective commitment to cultivate the knowledge, skills and values necessary for the full development of individuals and society as a whole.

For future research, longitudinal studies are suggested to evaluate the long-term impact of implemented interventions on educational quality and student retention in virtual Industrial Engineering programs. In addition, the relationship between student health care and academic performance in virtual environments can be further explored, identifying possible barriers and solutions to ensure equitable access to health services for all students.

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