

Lean Academy a Mathematical Model “Understanding of Needs Between Universities and Industry”

Ariza Miguel Ángel ¹, Martín Ricardo Andrés ², Rueda Milton Januario³, Sánchez Luz Marina ⁴.

1. Affiliation: Universidad Sergio Arboleda y Universidad EAN; slarizag@hotmail.com; <https://orcid.org/0000-0002-8753-8078>
2. Affiliation: Universidad Sergio Arboleda; ricand.martin@gmail.com; <https://orcid.org/0000-0001-6035-8336>
3. Affiliation: Universidad EAN; mramon.d@universidadean.edu.co; <https://orcid.org/0000-0002-0338-5327>
4. Affiliation: Universidad EAN; lusanchez@universidadean.edu.co; <https://orcid.org/0009-0003-1147-2783>

Abstract: Currently, there is a misalignment between the academic and business spheres; this gap is evident in the pressure faced by universities to adapt to the requirements of the fourth industrial revolution demanded by companies. This misalignment is caused by the lack of articulation between the competencies of academia graduates and the needs of companies in technological migration within their organizational processes, generating additional costs for organizations, associated with the complementary training of 4.0 competencies and staff turnover. Since, the lack of the mastery of the tools, methodologies or knowledge associated with industry 4.0, incurs additional costs of formal and non-formal training. In order to mitigate this gap between these actors, the objective of this research is the application of a deterministic model, which allows higher education institutions (HEIs) to be located in clusters according to the response variable obtained in the model, and thus, allow HEIs to design their strategies to meet these challenges. To achieve this objective, an instrument was designed to collect information from those involved in order to process the data in the proposed model, using quantitative analysis techniques. The findings made it possible to identify significant variables that directly affect the fulfillment of competencies required by the business sector within the framework of the fourth industrial revolution. In conclusion, it is possible to model the complex characteristics associated with the needs of organizations.

Keywords: process model; competency gap; deterministic model; project management; quality in higher education.

LEAN ACADEMY UN MODELO MATEMÁTICO “ENTENDIMIENTO DE NECESIDADES ENTRE LAS UNIVERSIDADES E INDUSTRIA”

Resumen: en la actualidad, se observa una desalineación entre el ámbito académico y el empresarial. Esta brecha se evidencia en la presión que enfrentan las universidades para adaptarse a los requisitos de la cuarta revolución industrial que demandan las empresas. La desalineación se origina por la falta de articulación entre las competencias de los egresados de la academia y las necesidades de las empresas en migración tecnológica al interior de sus procesos organizacionales, generando costos adicionales para las organizaciones asociados a la formación complementaria de competencias 4.0 y a la rotación de personal. Al no contar con el dominio de las herramientas, metodologías o conocimientos asociados a la industria 4.0, se incurre en sobrecostos de capacitaciones y entrenamiento formal y no formal. Para mitigar dicha brecha entre estos actores, el objetivo de investigación es la aplicación de un modelo determinístico que permite ubicar a las instituciones de educación superior (IES) en clústeres según la variable de respuesta obtenida en el modelo, permitiendo que las IES diseñen sus estrategias para afrontar estos desafíos. Para lograr este objetivo, se diseñó un instrumento que permitió recolectar información de los involucrados, para así procesar los datos en el modelo planteado, utilizando técnicas de análisis cuantitativo. Los hallazgos permitieron identificar variables significativas que afectan directamente al cumplimiento de competencias requeridas por el sector empresarial en el marco de la cuarta revolución industrial. Se concluye que es posible modelar las características complejas asociadas a las necesidades de las organizaciones.

Palabras clave: modelo de procesos; brecha en competencias; modelo determinístico; gestión de proyectos; calidad educación superior.

Introduction

This article presents the results of a research originating from the existing gap between the business sector and academia, by showing the non-fulfillment of the challenges that organizations have in the framework of implementing tools, methodologies, technologies and knowledge of the emerging industrial revolution 4.0, concerning the competencies being developed in engineering professionals at the undergraduate level [1,2].

As there is a gap in competency requirements between the business and academic sectors, companies self-manage or subcontract this requirement to entities other than higher education, providing it through courses, training and/or personalized training within company work teams. This generates curves of greater adaptation time of the personnel to new operative and tactical tasks and with greater difficulty to the strategic ones in the organizations. [3]. Due to the fact that the personnel who apply for and enter new positions do not have the competencies to start their work, requiring companies to incur in additional costs of training and adaptation to the culture of the organizations. Additionally, it is observed that the research projects developed by the academy are largely academic research projects and not applied to the needs of the business sector [4].

In recent years, higher education institutions (HEIs) have been reinforcing their activities in order to respond to the challenges that the business sector is demanding in the face of the fourth industrial revolution. It can be seen from the allocation of resources in the research seed beds and extension teams for consultancies and/or business projects that efforts and resources are generated, but these are efforts that follow the classic structure of HEI processes, where the mission processes of teaching, research and extension are articulated, without linking their strategy and structure to real-sector organizations [5].

At this stage, it becomes crucial to identify the key variables that influence the disparity between the business sector and the academic sector [6]. Seeking solutions, this research proposes the following hypothesis: by planning and designing a mathematical model that measures how well the competency needs of the business sector are met within the framework of Industry 4.0 in engineering programs, it will be possible to mitigate the gap between the academic and business sectors [7].

In order to verify the above hypothesis, the research objective is to plan and design a mathematical model for undergraduate engineering programs meeting the needs of the business sector in the framework of the industrial revolution 4.0. Using the DMAIC phases, which is part of the project management tools focused on the continuous improvement of organizational processes [8, 9]. For this research, the following four phases are used: 1. Definition, 2. Measurement, 3. Analysis and 4. Improvement phase – results.

To develop the proposed mathematical model in this research, it is important to understand the structure of the competency-based training model that HEIs have, in order to meet the requirements associated with the training needs of skills and knowledge in future graduates of engineering programs, who will be at the forefront of process management and are incorporating the elements that make up the industrial revolution 4.0, [10]. HEIs can voluntarily select and adopt an accreditation model based on the development and evaluation of learning competencies. Among the accreditation models, the following can be evidenced: ABET (Accreditation Board for Engineering and Technology), EUR-ACE (European Accreditation of Engineering Programs), Washington Accord and CDIO (Conceive-Design-Implement-Operate). These accreditation models aim to evaluate and assure the quality of engineering programs through rigorous and standardized processes. [11, 12].

Another approach to meet business sector needs is to comply with the requirements of high-quality accreditation for engineering programs. These guidelines are based on the objective of high quality accreditation of higher education programs, through the implementation of a culture of self-evaluation within their processes, to measure the degree of compliance with the requirements of stakeholders. [13].

To support the design of the mathematical model, a bibliometric analysis of the literature associated with the research was performed.

Subsection A: bibliometric analysis

A bibliographic review is carried out by means of the bibliometric analysis method. Its objective is to systematically identify, analyze, and visualize the publications and contributions related to the research topic. [14, 15].

For the development of the bibliometric analysis method, the following steps are followed: 1. Identification and selection of the databases to be used (primary sources.). 2. Identification of the keywords using the "browse by topic" search. 3. Construction of the search equations. 4. Analysis of documentation for each of the constructed searches. Generation of a comparative table, where the variables and methodologies used by the authors that are relevant to the current research were identified.

Within the bibliometric analysis, bibliographic linkage was developed, which is a type of similarity measure to categorize documents in specific and similar relationships [16]. This analysis considers the research areas of the authors, the interaction between keywords and the content of the article. For the present research, Scopus and ScienceDirect were used as the primary database search and query tools to construct the search equations to collect the necessary information for the analysis performed with the support of queries in Springerlink [17].

Subsection B: consultation of information relevant to the investigation

Within the required documentation to be consulted in the search equations, research associated with the development of competencies that meet the needs and challenges that organizations are presenting in the framework of the industrial revolution 4.0 must be identified. One of the pillars of competencies, is the evaluation of the performance of engineering programs, which can leverage the development of competencies with the application of the concept of quality, incorporating the evaluation of efficiency from an enveloping analysis of data [18].

Another pillar of competencies is the evaluation of educational quality, based on academic efficiency using data development analysis models, seen as the evolution of adequacy, in order to perform analysis of results, in search of higher levels of efficiency and a greater capacity for transformation of professionals who are trained in engineering programs [19].

Searches should include those associated with the methodology for measuring the quality of the educational system and its academic programs [20]. Zooming in on researches that develop a method to evaluate the academic efficiency of engineering programs or that perform cluster analysis to classify these programs according to their degree of achievement [21].

It is important for the development of the mathematical model of this research to involve consultations associated with internal quality assurance systems that promote the improvement of teaching and learning for future engineers who will be facing the challenges of organizations [22]. These challenges associated with the industrial revolution 4.0. can be evidenced inside the processes in organizations, where by failing to manage them, they will become limitations for companies [23].

One way to address these challenges is the path of automating organizational processes through data analytics and verifying compliance with new business rules using knowledge transfer models [24].

Methodology

The research methodology is a mixed approach, combining exploratory research, which involves a systematic review of existing and relevant literature, with quantitative research for the development of the mathematical model used in the study. The development of the research is presented in four phases: 1. Definition, 2. Measurement, 3. Analysis and 4. Improvement phase – results.

1. Definition phase, a diagnosis of the skills demanded by the business sector within the framework of Industry 4.0 is conducted by parameterizing a web scraping process to extract specific data from job offer websites [25]. To consolidate the information of competencies developed in engineering professionals at the undergraduate level by the Higher Education Institutions (HEI), two sources of information are used, the first is the source of the SNIES, obtaining the databases (DB) of the professional programs associated with engineering, and the second source of obtaining information, is the consolidation of the DB with the graduate profiles of the engineering programs identified in each of the web pages of the HEI.

2. Measurement phase, cross-checking of information between the DB of competencies that are demanded by the business sector in the framework of the industrial revolution 4.0, and the consolidated DB of the competencies that are declared in the graduate profiles of the academic programs. This seeks to measure the significance of the variables required in the process model, through an ANOVA model, with a confidence level of 0.95 [26]. ANOVA is a fundamental tool in research and data analysis, enabling researchers and professionals to make informed decisions based on comparisons of multiple groups

3. During the analysis phase, statistical software is used to process the data by means of an ANOVA, in order to identify and quantify the significant variables with respect to the response variable (Y) (number of competencies declared by the HEIs and that match those requested by the business sector in the framework of the industrial revolution 4.0).

4. Improvement phase - results, the significant variables identified in the analysis phase are used so that the IES can define the strategies they wish to develop to meet the needs of the business sector and thus be able to improve the position in which the mathematical model placed them.

Results

The results of the research are presented for each of the four phases of the methodology.

1. Results of the definition phase, to consolidate the competency needs required by the business sector, web scraping was parameterized, resulting in a database of 1,783 records detailing the characteristics required for various jobs. For the consolidation of the database of undergraduate engineering programs at HEIs, data was gathered from the SNIES information source and from graduate profiles published on HEI websites, accumulating a total of 69,764 student enrollment records, as shown in **Table 1**.

Table 1. Summary of SNIES query DB

Number of Engineering Academic Programs (undergraduate level)	Public IES	Private IES	Higher Education Institutions (HEI)	Number of Graduate Profiles (IES*Academic Program)
66	49	109	158	657

Source: authors (2024)

2. Results of the measurement phase, the cross-checking of information for each of the academic programs of the SNIES database against the database of records obtained with the web scraping parameterization was carried out. After the cross-checking of information, it is obtained that 19.5% of the 158 HEIs that offer a program directly associated with engineering, have explicitly stated in their graduate profiles the keywords associated

with the competencies required in the fourth industrial revolution. Likewise, 8.5% of job postings are related to the keywords associated with the terms used in the fourth industrial revolution.

3. Results of the analysis phase, to achieve the analysis by means of the ANOVA model, the following variables were analyzed: (1) **Sector [S]** (IES of the public or private sectors), (2) **High quality accreditation [A]** (high quality accredited and not high quality accredited) and (3) **Programs [R]** (number of undergraduate engineering programs). The scope of this analysis is determined if the means of multiple groups are significantly different from each other.

The respective hypotheses were defined with an alpha level of 0.05 for each of the variables:

- The null hypothesis (h_0) is associated with the fact that the variables: Sector [S], Accredited [A] and Programs [R] are significant for the response variable [Y].

To measure the significance of the variables that affect the process model, which has as a response variable (Y) the number of competencies declared by the HEIs and that match those requested by the business sector within the framework of the industrial revolution 4.0, the significance results are obtained using the "P-value" for each variable. See **Table 2, Source: authors (2024)**

Table 3 y **Source: authors (2024)**

Table 4 respectively.

Table 2 ANOVA test variable Sector [S]

Variable	Degrees of freedom	Sum of squares (SS)	Mean sum of squares (MS) variance	F statistician	P-value
Sector [S]	1	709,3	709,35	11,29	0,001
Error	150	9.422,6	62,82		
Total	151	10.132,0			

Source: authors (2024)

Table 3 ANOVA test of credited variable [A]

Variable	Degrees of freedom	Sum of squares (SS)	Mean sum of squares (MS) variance	F statistician	P-value
Accredited [A]	1	327,1	327,14	5,0	0,027
Error	150	9.804,8	65,37		
Total	151	10.132,0			

Source: authors (2024)

Table 4 ANOVA test variable Programs [R]

Variable	Degrees of freedom	Sum of squares (SS)	Mean sum of squares (MS) variance	F statistician	P-value
Programs [R]	16	3.560	222,53	4,57	0,000
Error	135	6.572	48,68		
Total	151	10.132			

Source: authors (2024)

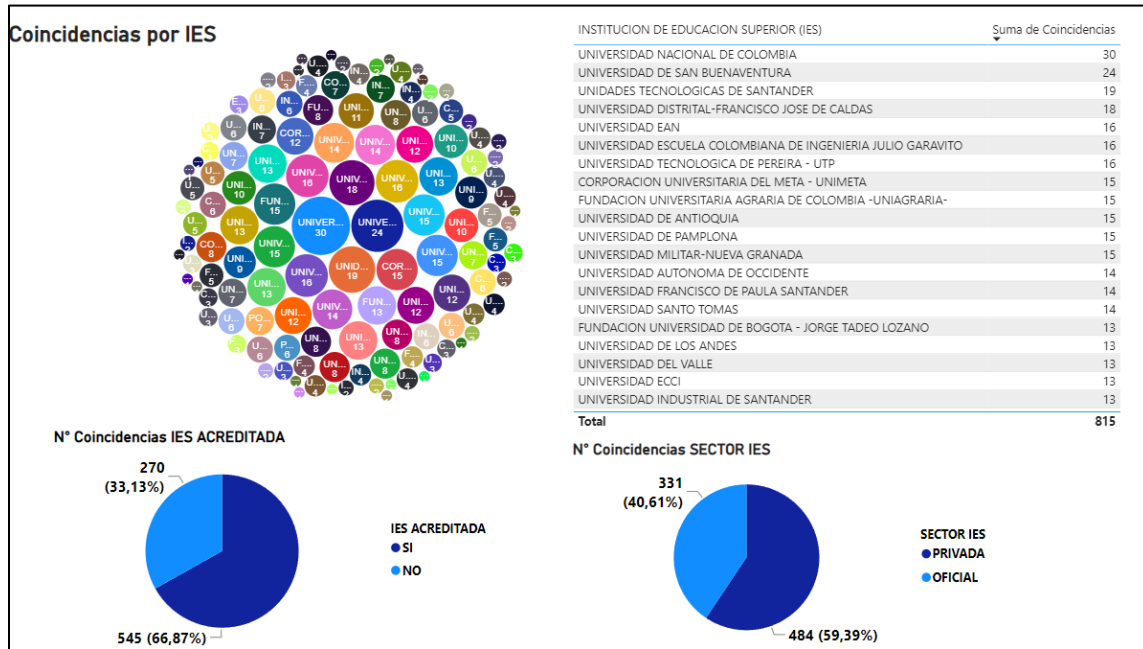
The experimental results of the pilot show that each of the categorical variables of: Sector [S], Accredited [A] and Programs [R] are significant for the response variable [Y] (see the p-values in the above tables).

4. Improvement discussion phase - results,

Figure 1 shows the results of the match analysis with the keywords associated with Industry 4.0. These results were obtained for each of the HEIs, which were used to identify the match between the words that refer to the competencies, skills and knowledge that were defined for the graduate profiles, this was done for each

engineering program versus the competencies required by the business sector published in the employment pages that were extracted through web scraping.

Figure 1 Result of the match analysis with the keywords associated with industry 4.0



Source: authors (2024)

With the DBs consulted from primary sources (open and non-open access documents), the mathematical model of the present research was designed. Based on the use of the logical Boolean operators and the defined keywords, we designed the search equations for the bibliometric analysis (see Table 5.)

Table 5. Search equations

N°	Combinatorial keywords	Bibliometric search
1	Model - Processes - Engineering Program	("Planning" OR "design" OR "analyze" OR "estimate") AND ("Process model" OR "business process") AND ("Academic program" OR "engineering program")
2	Compliance - Needs - Competencies - Business Sector	Compliance AND "Business requirements" AND ("Business skills" OR "business competences")
3	Gap - Academic Sector - Business Sector	("Planning" OR "design" OR "analyze" OR "estimate") AND ("Process model" OR "business process") AND ("Academic program" OR "engineering program") AND Gap
4	Case Study - Model - Processes - Engineering Program	"Case study" AND ("Process model" OR "business process") AND ("Academic program" OR "engineering program")
5	Quality - Improvement - Engineering Programs	Quality AND "Higher education" AND ("Academic program" OR "engineering program")
6	Quality Assurance - Higher Education	"Quality assurance" AND "Higher education" ("Academic program" OR "engineering program")

Conclusions

Higher Education Institutions (HEIs) are organizations that are recognized as educational entities in the public or private sector and are regulated by a competent body in each country. According to their classification, HEIs may choose in their strategic plan to be accredited as a high-quality entity or not. Within this research, it became evident that the sector variable (private and public) [S], as well as the high-quality accreditation variable (yes or no) [A], turned out to be significant for the response variable (Y) (number of competencies declared by the HEIs and that match those requested by the business sector within the framework of the industrial revolution4.0), subsequent validation through the ANOVA mathematical model.

After identifying the significance of the variables: sector [S] and accreditation [A], it was possible to conclude that 66.87% of HEIs that matched the requirements of the business sector in competencies, skills and knowledge associated with the industrial revolution 4.0 are high quality accredited entities. Meanwhile, in the analysis with the sector variable [S], it was found that 59.39% of the match with the requirements of the business sector are private HEIs.

With this research it was also possible to quantitatively demonstrate, by means of a deterministic model, that a HEI that decides to be accredited as a high-quality institution will have a direct effect on the score that the model will give it, since, being a significant variable, it will have an influence on the result of compliance with the needs of the companies in the real sector.

Likewise, the number of engineering programs at the undergraduate level that a HEI has affects the result of the number of coincidences of the keywords associated with the needs of the companies in the business sector. This implies that a HEI that has a greater number of programs aligned to the competencies requested by the business sector, will be better represented in scores compared to other HEIs, by diversifying its academic portfolio of programs in the different engineering knowledge areas aligned to the needs of the companies.

The proposed model made it possible to identify the number of existing coincidences (815 coincidences for all HEIs vs. keywords) as shown in **Figure 1**, which shows the HEIs in order from highest to lowest. This number of coincidences was obtained from the crossing of the databases consolidated in this research, which are: Industry 4.0 keywords, the profiles of the graduates of the engineering programs and the competences requested by the business sector.

These results open the door to future research, where a mathematical model complementary to the one presented in this research can be designed, including other variables of analysis, to be processed by other types of models, which allow predicting the behavior for the response variable (Y) (number of competencies declared by the HEIs and that match with those requested by the business sector in the framework of the industrial revolution 4.0), and thus be able to design classification clusters by academic engineering programs (not only for undergraduate, but also for graduate programs) and also by HEI. Being able to contemplate as main stakeholder the companies of the business sector, so that the pedagogical, academic and administrative strategies of the IES are oriented to the formation by competences for the future professionals, where they develop abilities to achieve a thinking of formulation and ingenious search of feasible solutions to the challenges of each sector of the industry of the country under study.

References

- [1] A. Janowski, O. Gonchar, and R. Yakovyshyn, "EDUCATION VS. ENTREPRENEURSHIP – BETWEEN THEORY AND PRACTICE: THE CASE OF SMES IN POLAND," *E a M Ekon. a Manag.*, 2023, doi: 10.15240/TUL/001/2023-1-007.
- [2] L. R. Rodríguez-Alegre, G. Trujillo-Valdiviezo, M. J. Egusquiza-Rodríguez, and R.-P. López-Padilla, "Revolución industrial 4.0: La brecha digital en Latinoamérica," *Rev. Arbitr. Interdiscip. Koinonía*, 2021, doi: 10.35381/r.k.v6i11.1219.
- [3] F. J. Ávila-Camacho and L. M. Moreno-Villalba, "Internet de las Cosas (IoT) Retos para las Empresas en la era de la Industria 4.0," *Pädi Boletín Científico Ciencias Básicas e Ing. del ICBI*, 2023, doi: 10.29057/icbi.v10i20.9516.
- [4] J. J. Marín Niño, C. Michelsen Niño, J. Ospina Rodríguez, and L. Rojas Oviedo, "Entre el consenso y el disenso. Una mirada a las competencias gerenciales desde la academia y la empresa," *Poliantea*, 2013, doi: 10.15765/plnt.v4i7.295.
- [5] M. Pap, R. Vdovic, and B. Baletic, "DESIGN THINKING METHOD IN SCIENTIFIC RESEARCH, EDUCATION

- AND BUSINESS PRACTICE,” *PROSTOR*, 2019.
- [6] P. I. Gómez Zepeda, A. Flores Sánchez, E. R. Poblano Ojinaga, M. A. Rodríguez Medina, and J. A. Pinto Santos, “Determinación de mejores prácticas de logística inversa asociadas a la competitividad a través del teorema de Bayes,” *RIDE Rev. Iberoam. para la Investig. y el Desarro. Educ.*, 2022, doi: 10.23913/ride.v13i25.1335.
- [7] M. Martín-González, D. Ondé, and C. Pérez-Esparrells, “El impacto de las competencias en la empleabilidad de los titulados universitarios de las universidades valencianas,” *Investig. en Econ. la Educ.*, 2015.
- [8] F. Tsung and K. Wang, “Six Sigma,” in *Springer Handbooks*, 2023.
- [9] C. W. Adams, P. Gupta, and C. E. Wilson, “The History of Six Sigma,” *Six Sigma Deployment*, 2020. .
- [10] L. Á. Salazar López, T. Carrasco Ruano, W. Correa Anchundia, J. Carrillo Cepeda, and E. Velasteguí López, “La gestión por competencias una herramienta clave para el desarrollo en el sector empresarial,” *Cienc. Digit.*, 2018, doi: 10.33262/cienciadigital.v2i1.2.
- [11] L. E. Peláez-Valencia, H. Trefftz, and I. A. Delgado-González, “Acreditación internacional de carreras de ingeniería,” *Rev. Educ. en Ing.*, 2020.
- [12] F. Q. Khan, S. M. Buhari, G. Tsaramirsis, and S. Rasheed, “A Study of Faculty Retention Factors in Educational Institutes in Context With ABET,” *Front. Educ.*, 2021, doi: 10.3389/educ.2021.678018.
- [13] W. U. Rincón-Báez, “ANÁLISIS DE INSTITUCIONES CON ACREDITACIÓN DE ALTA CALIDAD 2020,” *Boletín Estadístico*, 2024, doi: 10.15765/1949h366.
- [14] “Un análisis bibliométrico de evaluaciones de calidad de datos en sistemas de gestión académica,” *NOVASINERGIA Rev. Digit. CIENCIA, Ing. Y Tecnol.*, 2024, doi: 10.37135/ns.01.13.10.
- [15] S. de Souza, S. Breval Santiago, A. de Amorim Francisco Soares Filho, M. de Mendonça, and F. Lucena Oliveira, “Metanálisis de los modelos de madurez de la industria 4.0,” *Interciencia*, 2020.
- [16] M. del P. Escott-Mota, C. P. Bermúdez-Peña, and F. Flores-Agüero, “Análisis bibliométrico de la educación como bien común. Un enfoque en la transformación digital,” *Transdigital*, 2023, doi: 10.56162/transdigital200.
- [17] W. Reyes, “¿Qué son las Fuentes Primarias y Secundarias? - Lifeder,” 1. 2018.
- [18] E. Delahoz-Dominguez, R. Zuluaga-Ortiz, and M. Suarez-Sánchez, “A Six Sigma and DEA approach for learning outcomes assessment at industrial engineering programs,” *Int. J. Six Sigma Compet. Advant.*, 2023, doi: 10.1504/IJSSCA.2023.130283.
- [19] E. Delahoz-Dominguez, A. Mendoza-Mendoza, and D. Visbal-Cadavid, “EFFICIENCY OF ACADEMIC ENGINEERING PROGRAMS IN COLOMBIA: AN APPROACH THROUGH DATA ENVELOPMENT ANALYSIS,” *J. Eng. Sci. Technol.*, 2022.
- [20] R. Zuluaga-Ortiz, E. Delahoz-Dominguez, A. Períñan-Luna, J. Escorcía, F. Moreira-Villegas, and A. Arteta, “Evaluation of Educational Quality Under a Six Sigma Approach to Engineering Degrees in Colombia,” in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2022, doi: 10.1007/978-3-031-10539-5_13.
- [21] E. D. La Hoz, R. Zuluaga, and A. Mendoza, “Assessing and classification of academic efficiency in engineering teaching programs,” *J. Effic. Responsib. Educ. Sci.*, 2021, doi: 10.7160/ERIESJ.2021.140104.
- [22] N. T. T. Pham, C. H. Nguyen, H. T. Pham, and H. T. T. Ta, “Internal Quality Assurance of Academic Programs: A Case Study in Vietnamese Higher Education,” *SAGE Open*, 2022, doi:

10.1177/21582440221144419.

- [23] W. Wang, T. Chen, M. Indulska, S. Sadiq, and B. Weber, “Business process and rule integration approaches—An empirical analysis of model understanding,” *Inf. Syst.*, 2022, doi: 10.1016/j.is.2021.101901.
- [24] R. Torkhani, J. Laval, H. Malek, and N. Moalla, “Intelligent Framework for Business Process Automation and Re-engineering,” in *9th International Conference on Intelligent Systems 2018: Theory, Research and Innovation in Applications, IS 2018 - Proceedings*, 2018, doi: 10.1109/IS.2018.8710523.
- [25] F. A. Riski, N. Selviandro, and M. Adrian, “Implementation of Web Scraping on Job Vacancy Sites Using Regular Expression Method,” in *2022 1st International Conference on Software Engineering and Information Technology, ICoSEIT 2022*, 2022, doi: 10.1109/ICoSEIT55604.2022.10029964.
- [26] P. Stoker, G. Tian, and J. Y. Kim, “Analysis of variance (Anova),” in *Basic Quantitative Research Methods for Urban Planners*, 2020.