

STUDIES OF REGIONAL, NATIONAL AND INTERNATIONAL NEEDS OF THE SYSTEMS ENGINEERING PROGRAM OF THE CORPORACIÓN UNIVERSITARIA AMERICANA

Sebastián CARDONA-ACEVEDO¹
Luisa YEPES OSPINA²
Jhon Edison COLORADO FLÓREZ³
Arturo ARENAS-FERNÁNDEZ⁴

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ABSTRACT: This study analyzes the regional, national, and international relevance of the Systems Engineering program at Corporación Universitaria Americana in the context of rapid digital transformation and increasing demand for advanced technological competencies. The study adopted a mixed-methods approach, combining documentary analysis, secondary data review, international benchmarking, and curricular gap analysis to assess alignment between the current curriculum and requirements from public policies, the productive sector, technological trends, and international frameworks for computing education. The findings indicate heterogeneous curricular relevance across the three levels of analysis. The program demonstrates strengths in software development, computational thinking, project-based learning, and interdisciplinary problem-solving. However, gaps remain in the systematic, transversal integration of artificial intelligence, cloud computing, cybersecurity, advanced data analytics, software architecture, and intelligent systems. The analysis also identifies limited structural articulation with regional innovation ecosystems and industry, as well as opportunities to strengthen curricular flexibility and specialization pathways in response to evolving labor market demands. These findings suggest that the main challenge is not the absence of emerging technologies in the curriculum, but their predominantly incremental and insufficiently integrated incorporation. Accordingly, the study proposes a competency-based curricular redesign focused on the transversal integration of emerging technologies, continuous curriculum updating, stronger university–industry collaboration, interdisciplinary learning, and flexible specialization pathways. This framework can strengthen graduate employability, institutional competitiveness, and the continuing relevance of Systems Engineering education in a rapidly changing digital environment.

Keywords: Artificial intelligence, curriculum relevance, digital transformation, higher education, systems engineering.

¹ School of Engineering, Corporación Universitaria Americana, Colombia, 50010, sacevedo@americana.edu.co, ORCID: <https://orcid.org/0000-0002-6192-2928>

² Technology Administrator. School of Education, Corporación Universitaria Americana, lyepesmed@americana.edu.co, ORCID: <https://orcid.org/0009-0009-0170-7626>

³ School of Engineering, Corporación Universitaria Americana, Colombia, 50010, coordinacioningenieriamed@americana.edu.co, ORCID: <https://orcid.org/0009-0000-5561-880X>

⁴ Office of the Vice President for Academic Affairs, Corporación Universitaria Americana, Colombia, 50010, aarenasf@americana.edu.co, ORCID: <https://orcid.org/0000-0001-7707-5981>

INTRODUCTION

The relevance of higher education programs is a fundamental criterion for ensuring their capacity to respond to social, productive, scientific, and technological transformations in their surrounding environment. Within this context, the Systems Engineering program at Corporación Universitaria Americana is structured according to the regulatory framework established by the accreditation granted through Resolution 023029 of November 30, 2021, issued by the Ministry of National Education. Although this recognition establishes formal quality standards and provides a foundation for the educational proposal, its validity should not be treated as static, given the rapid transformation of the educational, technological, and labor environment. In particular, processes associated with digital transformation, automation, and the data-driven economy have substantially altered the characteristics and competencies required in the world of work (World Bank, 2019; OECD, 2020). Therefore, accreditation should be regarded as a baseline subject to continuous evaluation and updating in response to emerging environmental dynamics.

From this perspective, the National Accreditation Council's guidelines identify relevance as an essential component of quality, understood as the capacity of academic programs to respond coherently and proactively to the needs of the social, productive, and scientific environment. However, transformations in the information and communications technology ecosystem reveal a growing demand for professional profiles whose competencies extend beyond traditional training in programming and infrastructure management. Labor market analyses and international projections point to a need for hybrid professional profiles that integrate technical, analytical, and strategic knowledge, particularly in advanced analytics, artificial intelligence, cybersecurity, and digital solutions architecture (World Economic Forum, 2023). This transformation aligns with international frameworks for computing education, which promote integrative, competency-based approaches (Association for Computing Machinery (ACM) & IEEE Computer Society (IEEE-CS), 2020).

Consequently, a tension emerges between curricula grounded in traditional disciplinary structures and an environment that requires transversal and interdisciplinary capabilities to address complex problems. International organizations have recognized this situation in their

analyses of the challenges digital transformation poses to education and employment (CEPAL, 2022; UNESCO, 2021). The potential misalignment between academic training and environmental demands may affect both graduate employability and academic programs' capacity to participate in regional and national innovation dynamics. In the Colombian context, this need becomes particularly relevant because of the articulation between state policies on digital transformation, such as those established by the Departamento Nacional de Planeación (2019) through CONPES 3975, and the commitments established by the Departamento Nacional de Planeación (2023) in the National Development Plan 2022–2026.

Despite the growing importance of curricular relevance, evaluation often relies on isolated indicators, regulatory compliance exercises, graduate employability measures, or comparisons with labor-market needs. These approaches may provide valuable information, but they do not necessarily integrate, within a single analytical framework, the relationships among public policy, productive-sector demands, and the discipline's future evolution. This limitation is particularly significant in Systems Engineering, where technological change can rapidly alter the knowledge, skills, and professional roles expected of graduates. Therefore, a more comprehensive evaluation is needed to determine not only whether a curriculum currently responds to its environment, but also whether it is positioned to anticipate emerging transformations.

In this context, the curricular relevance of the Systems Engineering program can be examined through a multidimensional perspective that moves beyond an exclusively descriptive approach and links curricular structure to environmental dynamics. For this purpose, three complementary dimensions are considered: vertical, horizontal, and prospective relevance. Vertical relevance examines the program's correspondence with public policies and national priorities concerning education, development, and digital transformation. At this level, the Departamento Nacional de Planeación (2023) establishes digitalization as a cross-cutting axis for competitiveness and equity, while the Departamento Nacional de Planeación (2019), through CONPES 3975, provides guidelines for developing human capital associated with emerging technologies, particularly in areas such as artificial intelligence and the digital economy. This orientation also relates to the Sustainable Development Goals, particularly

SDGs 4, 8, and 9, which link quality education with decent work and innovation. Nevertheless, international evidence indicates that traditional Systems Engineering curricula may incorporate these orientations only marginally, thereby creating a gap between public policy objectives and their effective translation into professional competencies (UNESCO, 2021).

Horizontal relevance, in turn, makes it possible to assess the alignment between academic training and the productive sector's dynamics. The evolution of labor demand toward hybrid technological profiles highlights the need for professionals who can operate in environments where digital technologies, organizational processes, and new business models converge (World Bank, 2019; World Economic Forum, 2023). Insufficient articulation with the productive sector may lead to predominantly reactive curricular processes, limiting the capacity to anticipate market needs and affecting both graduate employability and the program's contribution to regional innovation processes.

Finally, prospective relevance incorporates technological trends and future disciplinary transformations as references for curricular updating. Frameworks developed by the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers show Systems Engineering expanding into areas such as data science, cloud computing, cybersecurity, and artificial intelligence, implying changes in both educational content and training methods (ACM & IEEE-CS, 2020). In this regard, one of the main challenges is updating curricula quickly enough to keep pace with technological evolution, which may create a gap between the competencies developed during academic training and those required in emerging professional contexts.

Thus, the research problem focuses on the potential dissonance between the current educational structure of the Systems Engineering program at Corporación Universitaria Americana and the current and future demands of the digital, productive, and regulatory environment. Identifying this potential gap requires assessing not only compliance with regulatory standards but also the curriculum's capacity to respond to technological transformations, public policies, productive-sector needs, and international disciplinary trends. Consequently, the program needs an evidence-based curricular evaluation process that identifies opportunities to update content, methodologies, and competencies, while strengthening articulation with the productive and

technological environment. This approach is essential to ensuring the program's academic sustainability and relevance in the medium and long term, in accordance with international standards for computing education (ACM & IEEE-CS, 2020).

The main contribution of this study lies in proposing and applying an integrated analytical perspective that simultaneously examines three dimensions of curricular relevance: vertical relevance, associated with public policies and national development priorities; horizontal relevance, related to the requirements of the productive and labor environment; and prospective relevance, focused on technological and disciplinary trends that may shape future professional practice. Rather than limiting the analysis to regulatory compliance or a descriptive review of the curriculum, this approach enables identification of convergences, gaps, and curricular tensions across multiple sources of environmental demand. In practical terms, the findings can provide evidence to support curriculum updating, competency development, academic planning, and stronger articulation between the university, the productive sector, and public policy. Methodologically, the proposed multidimensional framework also offers a potentially transferable approach for evaluating curricular relevance in other engineering- and technology-oriented higher education programs operating in contexts of accelerated technological change.

Accordingly, the objective of this study is to analyze the curricular relevance of the Systems Engineering program at Corporación Universitaria Americana in relation to the current and future demands of the educational, productive, technological, and regulatory environment, through a multidimensional analytical model based on vertical, horizontal, and prospective relevance, to identify curricular gaps and opportunities for updating and improvement.

Accordingly, the guiding research question is: To what extent does the Systems Engineering program at Corporación Universitaria Americana respond to the current and future demands of the educational, productive, technological, and regulatory environment, ¿and what curricular gaps and opportunities for improvement can be identified?

METHODOLOGY

The study methodology uses a mixed-methods design focused on evidence triangulation, aiming to systematically compare the Systems Engineering program's curriculum with the dynamics of the regulatory, productive, and technological environment. This methodological approach moves beyond unidimensional frameworks, enabling relational analysis in which curricular decisions are evaluated for coherence across multiple sources of evidence. This approach mitigates the risk of biases arising from partial diagnoses.

The methodological approach centers on a tripartite integration of document analysis, secondary data, and international benchmarking, establishing a cross-validation framework. The documentation analysis identifies explicit priorities in public policies and regulatory frameworks, while secondary data analysis reveals trends in labor demand and the evolution of the ICT sector. Benchmarking, for its part, provides a comparative reference point that allows evaluation of the program's positioning against international standards, particularly in curriculum updates and the development of emerging competencies. This methodological approach responds to the need to interpret the curriculum not as an autonomous construct, but as an open system conditioned by multiple levels of influence.

The documentary corpus comprised 25 documents selected for their direct relevance to curricular development, digital transformation, ICT-sector requirements, technological trends, professional competencies, and international frameworks for computing and Systems Engineering education. The corpus included institutional and curricular documents, national public-policy and regulatory documents, sectoral and labor-market reports, and international guidelines and reports related to technological and professional trends.

The documentary search was conducted through official repositories and institutional websites of national and international organizations relevant to the study, including governmental and educational entities, as well as organizations such as the OECD, UNESCO, World Bank, World Economic Forum, ACM, IEEE, and INCOSE. The search was guided by combinations of terms related to “Systems Engineering,” “computing education,” “curriculum,” “digital transformation,” “ICT skills,” “professional competencies,” “artificial intelligence,” “data science,” “cybersecurity,” and “cloud computing.” The search prioritized

documents directly related to the regional, national, international, and prospective dimensions examined in the study.

Documents were included when they provided explicit evidence regarding at least one of the following aspects: public-policy priorities associated with education and digital transformation; ICT-sector and labor-market requirements; technological and professional competency trends; curricular guidelines for computing or Systems Engineering education; or international standards relevant to the future development of the discipline. The study excluded documents that did not provide information directly applicable to the study's analytical dimensions, duplicated information already represented in the corpus, or lacked sufficient content for curricular comparison.

The study uses content analysis, a qualitative research method that systematically examines textual materials to identify patterns or themes (Esmaeili et al., 2025). In this case, the analysis focuses on strategic documents, including development plans, digital transformation policies, sector guidelines, international frameworks, and specialized reports, to identify analytical categories related to competencies, priority areas, technological domains, and training approaches.

After selecting the documents, the evidence was classified according to the analytical dimensions established for the study. Vertical relevance included information on public policies, regulatory frameworks, and national development priorities; horizontal relevance incorporated evidence on productive-sector requirements, labor-market dynamics, and professional competencies; and prospective relevance included technological trends, international disciplinary frameworks, and emerging areas of professional practice. Competencies, technological areas, training approaches, and environmental demands then organized the information extracted from each document.

This process is complemented by a gap analysis that compares the current curriculum structure with the competencies required by the environment, helping identify specific misalignments in areas such as data analytics, artificial intelligence, cybersecurity, cloud computing, and software architecture. Furthermore, a technology monitoring exercise, based on a review of scientific literature and specialized reports, identifies emerging trends and

evaluates the program's capacity to respond to future professional and technological scenarios.

The units of analysis are defined in a manner consistent with the study's purpose. First, the program's curriculum serves as the internal reference point and is analyzed in terms of content, competencies, and training structure. Second, labor-market and productive-sector demands are examined using secondary information from national and sectoral sources, including information on labor-market integration, occupational profiles, technological requirements, and skills gaps. Third, global technological and disciplinary trends are addressed through reports and frameworks from national and international organizations, whose evidence is used to contextualize the evolution of Systems Engineering and related computing disciplines.

The analytical procedure involved four stages. First, the relevant documentary and secondary sources were identified and selected according to the established criteria. Second, the information contained in these sources was classified according to the vertical, horizontal, and prospective dimensions of relevance. Third, the competencies and technological areas identified in the external environment were mapped against the Systems Engineering program's subjects, competencies, and training structure. Finally, the resulting correspondences and discrepancies were synthesized through curricular alignment and gap-analysis matrices, allowing the identification of strengths, partial alignments, structural gaps, and opportunities for curricular improvement.

The analytical process is operationalized through tools that facilitate information integration. Curriculum alignment matrices map correspondence between subjects and essential competencies, while policy-curriculum correspondence matrices make explicit the relationship between regulatory guidelines and the program's educational structure. These tools support systematic information organization, enabling identification of structural gaps, redundancies, and opportunities for curriculum innovation.

The study triangulated evidence by comparing findings across sources rather than interpreting each document independently. The study contrasted public-policy priorities, productive-sector and labor-market demands, international frameworks, and technological

trends with the curriculum to identify areas where multiple sources converged. This procedure strengthened the consistency of the curricular diagnosis and supported the assessment of the program from regional, national, international, and prospective perspectives.

Thus, the methodology is not confined to describing the program's current state; rather, it generates evidence to support curricular decision-making. Integrating documentary analysis, secondary data, international benchmarking, curricular mapping, and gap analysis makes it possible to evaluate curricular relevance as a dynamic condition shaped by technological evolution, productive-sector demands, public policy, and changes in professional competencies.

RESULTS

A relevance analysis of the Systems Engineering program reveals a heterogeneous mix of alignments and gaps at the regional, national, and international levels. This analysis identifies structural tensions that directly affect curricular decision-making.

At the regional level, particularly in Antioquia, the productive ecosystem is becoming increasingly complex as technology clusters consolidate and business demand for advanced digital solutions grows. Departmental plans and chambers of commerce have prioritized competitiveness agendas in areas such as data analytics, specialized software development, and digital business transformation. However, a thoroughgoing analysis of the curriculum reveals only partial coverage of these areas, with an overwhelming emphasis on conventional programming fundamentals and infrastructure. This creates a digital talent gap, evident in the challenges companies face in identifying suitable candidates and the program's limited capacity to engage regional innovation networks meaningfully. The relationship with ICT clusters is an underutilized opportunity, as the current articulation does not translate into structural curricular adjustments or the co-creation of training pathways geared toward the specific needs of the business sector.

At the national level, the program's relevance is contested by strategic priorities set out in instruments such as CONPES 3975 of 2019, which establishes clear guidelines for developing capabilities in artificial intelligence and digital transformation. The structural deficit of ICT talent has been identified as an obstacle to the country's competitiveness by both the Ministry of National Education and the Ministry of Information and Communications Technologies. This has put direct pressure on training programs to accelerate curriculum updates. However, the evidence indicates that incorporating these areas into the analyzed program reflects more of an incremental approach than a profound transformation of the graduate profile. This gap between the training offered and the profiles required in the labor market creates career paths that, while functional, do not necessarily align with the highest value-added segments of the ICT sector. The fundamental tension lies in the speed of institutional responses to a national environment that requires sophisticated skills within increasingly constrained timeframes.

On an international and forward-looking level, a discrepancy becomes increasingly apparent when the program is compared with global trends identified by organizations such as the World Economic Forum and technical standards promoted by the IEEE. The consolidation of emerging technologies, including but not limited to artificial intelligence, cloud computing, cybersecurity, and data science, has significantly redefined professional profiles in systems engineering. This redefined profile reflects a shift in emphasis from operational skills to analytical, design, and complex systems integration capabilities. In this context, benchmarking against international programs reveals greater curricular flexibility, cross-cutting integration of these technologies, and an orientation toward project-based learning and real-world problems. The primary deficit identified is the program's limited capacity to integrate these transformations systematically, which impedes its academic competitiveness and its graduates' international mobility.

The analysis indicates that the program's relevance depends on balancing curricular stability with environmental dynamism. The disparities identified at the three levels analyzed point to the need for structural reconfiguration. Consequently, there is an urgent need to transition to a flexible curricular model, aligned with the productive sector and global trends. In this model, content updates, the integration of emerging competencies, and links with innovation ecosystems become central pillars to guarantee the program's relevance and sustainability.

Table 1

Analytical matrix of alignment between competencies of the Systems Engineering program of the American University Corporation and demands of the environment

Program competencies	Skills demanded by the environment	Source of demand	Alignment level	Evidence	Gap identified
Software programming and development	Modern Software Engineering and Agile Development	Mercado TIC, World Economic Forum	Medium-High	High performance (92%) in software development	Partial integration of DevOps, automated testing, and modern architecture
Development of technological solutions	Software Architecture and Scalable Systems	Association for Computing Machinery	Medium	Integrated projects applied to real-world problems	Lack of explicit focus on architecture and scalability at the curricular level
Databases and information management	Data Science and Advanced Analytics	OECD	Medium-High	Inclusion of Data Analytics and high performance (90%)	Limited cross-curricular integration with other areas of the curriculum
Technological infrastructure	Cloud Computing and Distributed Systems	IEEE	Low-Medium	Syllabus adjustments and curriculum updates	Absence of a structured approach to cloud computing
Computer security	Advanced Cybersecurity	World Economic Forum	Medium	Inclusion of Advanced Cybersecurity	Coverage still localized, without cross-curricular integration
Artificial intelligence	Automation, Machine Learning, and	Departamento Nacional	Medium	Inclusion of AI and	Lack of consolidation as a structural

	Intelligent Systems	de Planeación		Machine Learning	axis of the curriculum
Technological project management	Agile Methodologies and Digital Transformation	World Bank	Medium	Incorporation of Agile methodologies into the syllabus	Need for greater practical depth in real-world environments
Computational thinking and problem-solving	Solving Complex Problems in Interdisciplinary Environments	UNESCO	High	80% in complex problem-solving	Lack of systematization of interdisciplinary experiences
Interdisciplinary work	Knowledge Integration in Innovation Ecosystems	Clústeres, entorno regional	Medium-High	Interdisciplinary projects with social impact	Limited formal articulation with clusters and the productive sector
Flexible training	Personalized Learning Pathways and Adaptive Learning	Tendencias globales	High	Elimination of prerequisites and increased electives	Lack of strategic guidance in specialization pathways
Internationalization	Global Competencies and Academic Mobility	OCDE, mercado global	Medium	International mobility and credit recognition	Low level of external mobility
Integration of theory and practice	Project-Based Learning	Association for Computing Machinery	High	Projects with social and technological impact	Need for greater engagement with companies

DISCUSSION

The findings provide evidence of a heterogeneous level of curricular relevance in the Systems Engineering program, reflecting both strengths in established competencies and gaps in responding to emerging technological and productive demands. The discussion therefore interprets these results in relation to previous research on engineering education, competency development, technological transformation, and university–industry alignment, with particular attention to the regional, national, and international dimensions considered in the study.

Analysis of Results

The results show that a heterogeneous pattern of alignment across regional, national, and international levels characterizes the Systems Engineering program's curricular relevance. Rather than showing a general lack of relevance, the findings indicate that the program has incorporated several competencies demanded by the contemporary technological environment. However, their integration remains largely incremental and insufficiently systemic. This is particularly evident in the shift from conventional technical competencies to emerging capabilities in artificial intelligence, data science, cloud computing, cybersecurity, software architecture, and complex systems integration.

At the regional level, the main challenge is the gap between the productive ecosystem's technological dynamism and the curriculum's capacity to respond structurally to these transformations. Although the program includes software development, data analytics, and technological solution development, their articulation with regional productive demands remains limited. The medium and medium-high alignment observed for these competencies indicates a strong curricular foundation; however, limited connections with innovation networks and technology clusters restrict the development of specialized, context-responsive learning pathways. This finding is consistent with Orosco and Mejía (2022), who emphasize the importance of correspondence between university training, national development priorities, and business-sector requirements. Consequently, curricular relevance should not be understood merely as the presence of technological subjects, but as the capacity to

translate environmental demands into competencies, learning experiences, and professional profiles.

The most significant regional gaps therefore lie not necessarily in the absence of technological topics, but in their depth and transversal integration. Data analytics, artificial intelligence, and cybersecurity are incorporated into the program, but they do not consistently function as structural axes across the curriculum. This distinction is relevant because technological relevance increasingly depends on knowledge integration rather than the isolated addition of new subjects. Cameron et al. (2019) argue that growing technological and systemic complexity requires educational structures that integrate knowledge and develop competencies appropriate to complex professional environments. Similarly, research on competency-based Systems Engineering education emphasizes the importance of systematically identifying competencies through academic and industry perspectives. Thus, curricular updating should move beyond adding courses and instead promote stronger connections among learning outcomes, pedagogical strategies, projects, and competencies.

At the national level, the incorporation of artificial intelligence, machine learning, agile methodologies, and other emerging areas demonstrates institutional recognition of technological priorities. Nevertheless, these developments have occurred progressively without a corresponding transformation of the graduate profile. The central challenge is therefore curricular responsiveness: technological and labor-market demands are evolving faster than formal curricular structures can be modified. This tension between curricular stability and environmental dynamism helps explain why several competencies achieve only moderate alignment despite the existence of relevant subjects and activities.

This issue is particularly important in Systems Engineering because professional practice increasingly requires the capacity to understand, design, integrate, and manage complex technological systems rather than merely execute operational or programming tasks. Buede and Miller (2024) emphasize the systemic nature of engineering design, in which requirements, architecture, components, stakeholders, and system-level objectives must be considered as an integrated whole. Jazebizadeh et al. (2010) similarly demonstrate the usefulness of a systems engineering approach for structuring academic programs around

complex technological environments. Therefore, the present findings suggest that curricular relevance would be strengthened by adopting a more explicit systems perspective in organizing and integrating competencies.

The international and prospective dimension presents the most pronounced structural challenge. The low-medium alignment identified for cloud computing and distributed systems, along with the medium alignment observed for artificial intelligence and advanced cybersecurity, indicates that technologies shaping contemporary engineering practice have not yet been sufficiently integrated into the curriculum. Current engineering education research similarly highlights disparities between university curricula and industry requirements, particularly regarding emerging technologies, practical competencies, adaptability, analytical thinking, and systems thinking. The issue is therefore not simply whether a technology is taught, but whether students develop the capacity to integrate technologies and apply them to complex, uncertain, and interdisciplinary problems.

Internationalization also represents an important area for improvement. Although the program provides mechanisms for electives, credit recognition, and academic mobility, external mobility remains limited. The international dimension of engineering education extends beyond mobility and includes competencies that enable graduates to operate effectively in culturally and technologically diverse environments. Bourn and Neal (2008) emphasize the importance of global competencies in engineering education, while Marnewick and Handley (2022) identify cultural awareness, communication, ethics, teamwork, and other international competencies as relevant components of Systems Engineering education. Thus, the program could strengthen internationalization by incorporating global competencies into curricular outcomes, projects, collaborative activities, and professional experiences.

Despite these gaps, the program demonstrates important strengths. The strong alignment of computational thinking, problem-solving, flexible training, and project-based learning provides a solid foundation for curricular transformation. The 80% performance in complex problem-solving and the strong alignment of project-based learning indicate that the program already has pedagogical mechanisms that can support technological and interdisciplinary

integration. These strengths should therefore be used as platforms for incorporating emerging technologies rather than being replaced by an entirely new curricular structure. This approach is consistent with international perspectives that emphasize practical, real-world experiences, interdisciplinary competencies, and continuous adaptation in Systems Engineering education.

The incorporation of intelligent technologies also deserves particular attention. Reyes García et al. (2024) illustrate the growing potential of intelligent systems within Systems Engineering education. Likewise, recent research indicates that artificial intelligence can contribute to technical, methodological, social, and personal competencies such as programming, data analytics, problem-solving, teamwork, adaptability, communication, ethics, and continuous learning. In this case, including artificial intelligence and machine learning represents progress toward technological relevance. However, their medium alignment indicates they have not yet acquired the transversal role required to reshape the professional profile.

Overall, the analytical matrix demonstrates that curricular relevance is multidimensional. The program exhibits strong foundations in software development, computational thinking, project-based learning, and flexible training, while showing more pronounced gaps in cloud computing, advanced systems architecture, interdisciplinary integration, international mobility, and the transversal consolidation of emerging technologies. The central finding is therefore not a generalized curricular deficiency, but an asymmetric capacity for adaptation: the program responds more effectively to established competencies than to rapidly evolving technological and professional requirements.

These findings point toward a transition from a predominantly content-oriented curriculum toward a more flexible, integrated, and ecosystem-oriented model. Such transformation should strengthen university–industry collaboration, incorporate real-world technological challenges, expand interdisciplinary projects, establish clearer specialization pathways, and embed emerging technologies across multiple curricular areas. Consequently, the relevance of the Systems Engineering program should be understood as a dynamic condition that

requires continuous monitoring of technological, productive, and societal transformations, rather than as a fixed characteristic of the curriculum.

Comparison with Previous Studies

The findings of this study are broadly consistent with previous research examining the relationship between Systems Engineering education, technological transformation, and professional requirements. However, the results extend existing contributions by demonstrating that curricular alignment varies substantially across regional, national, and international dimensions of relevance.

A major point of convergence concerns the need to establish stronger relationships between academic curricula and productive-sector requirements. Orosco and Mejía (2022), in their study of the pertinence of a Systems Engineering program in Nicaragua, emphasized the importance of relating academic training to national development priorities and business-sector demands. A similar situation emerges in the present study, where the program shows partial alignment with regional requirements, particularly in advanced software development, data analytics, digital transformation, and emerging technological solutions. Nevertheless, the present findings indicate that the challenge extends beyond identifying labor-market needs: the critical issue is the institutional capacity to translate these demands into systematic curricular transformations.

This result is also consistent with Cameron et al. (2019), who argue that increasing technological and systemic complexity requires educational structures capable of preparing professionals for increasingly complex engineering environments. In the present study, this challenge is reflected in the medium alignment identified for software architecture, artificial intelligence, cybersecurity, and technological project management, as well as the low-medium alignment observed for cloud computing and distributed systems. These findings suggest that curricular relevance cannot be sustained by periodically incorporating isolated technological topics. Instead, it requires a comprehensive transformation of competencies, learning experiences, and relationships among curricular components.

The results also converge with research addressing the gap between employer expectations and academic curricula. Studies on Systems Engineering competency expectations identify relatively slow feedback mechanisms among employers, students, and universities, limiting academic programs' capacity to respond to rapid technological and industrial transformation. This situation closely parallels the central tension identified in the present study between curricular stability and environmental dynamism. Consequently, medium or medium-high alignment should not necessarily signal complete relevance; rather, it may indicate that the curriculum responds effectively to established requirements while struggling to anticipate emerging ones.

The comparison with Jazebizadeh et al. (2010) further reinforces the importance of a systemic approach to curriculum design. Their work shows how Systems Engineering principles can structure academic programs around the requirements of complex technological fields. The present study reaches a complementary conclusion: although several environmentally demanded competencies are already incorporated, their articulation remains insufficient in areas such as systems architecture, cloud computing, artificial intelligence, interdisciplinary work, and university-industry collaboration. Thus, this research contributes not only by identifying the presence or absence of competencies, but also by assessing the degree to which these competencies are structurally integrated into the curriculum.

Internationalization represents another important point of comparison. Bourn and Neal (2008) emphasize developing global competencies in engineering education, while Marnewick and Handley (2022) show how Systems Engineering curricula can deliberately incorporate international competencies through communication, teamwork, cultural awareness, and exposure to different perspectives. These findings align with this perspective because internationalization remains an area of comparatively weaker alignment. Although mechanisms for mobility and credit recognition exist, limited external mobility suggests that internationalization has not yet become a sufficiently transversal component of the educational experience. Accordingly, international relevance should encompass not only

mobility opportunities but also the competencies required to participate effectively in global and culturally diverse technological environments.

The findings also converge with international approaches to Systems Engineering curriculum development. INCOSE (2022) emphasizes that Systems Engineering education must remain responsive to changing technologies and practices while developing interdisciplinary, technical, leadership, and professional competencies. This perspective is particularly relevant because the present results demonstrate that curricular relevance is context-dependent. The program should therefore not simply reproduce international models, but combine internationally recognized competencies with regional and national productive requirements. In this context, the high alignment observed for computational thinking, problem-solving, flexible training, and project-based learning constitutes an important foundation for integrating emerging competencies without eliminating existing strengths.

Another point of convergence concerns practical and interdisciplinary learning. The present study identifies strong alignment in integrating theory and practice and in project-based learning, while also noting limitations in articulating these experiences with companies and innovation ecosystems. This finding aligns with systems engineering education models that emphasize practical, real-world experience and multidisciplinary collaboration. INCOSE similarly highlights the importance of broad systems competencies, cross-disciplinary collaboration, and practical learning connected to stakeholder needs. The distinctive contribution of the present study is to locate this challenge specifically within university-industry articulation: project-based learning is already present, but its potential for curricular co-creation with the productive sector remains underdeveloped.

Artificial intelligence and intelligent technologies constitute another relevant area of convergence. Reyes García et al. (2024) demonstrate the feasibility of incorporating intelligent technological solutions into Systems Engineering education. In the present study, artificial intelligence and machine learning are already included, but their medium alignment indicates that they have not yet been consolidated as transversal curricular axes. This distinction demonstrates that technological incorporation and curricular transformation are not equivalent processes. A program may include an emerging technology without

substantially transforming its competencies, pedagogical strategies, or professional profile. Current Systems Engineering perspectives similarly emphasize the growing importance of digital transformation, AI, data, cybersecurity, cloud computing, and other technologies within future professional competencies.

Overall, the comparison with previous studies reveals convergence around four fundamental principles: responsiveness to technological change, alignment with industry requirements, development of interdisciplinary and international competencies, and integration of practical learning experiences. Nevertheless, this study adds a perspective by organizing these dimensions within a three-level framework of regional, national, and international/prospective relevance. This approach makes it possible to identify asymmetries that may remain hidden when curricular relevance is evaluated from a single perspective.

The study's main contribution is therefore not identifying entirely new challenges, but contextualizing and integrating them. Previous research has generally focused on specific dimensions, such as international competencies, curriculum design, technological complexity, or university-business alignment. This analysis brings these dimensions together to show that curricular relevance results from their interaction.

Accordingly, the evidence indicates that the Systems Engineering program is neither disconnected from its environment nor fully aligned with it. Rather, it occupies an intermediate position, with strong foundations in established competencies and more limited responsiveness to rapidly emerging technological, productive, and international demands. This finding reinforces the view that curricular relevance should be treated as a continuous process of adaptation and feedback among universities, industry, technological developments, and societal needs. This approach provides a basis for moving from periodic curricular updates to a more dynamic, context-sensitive model of curriculum development.

Implications

The findings of the curricular relevance analysis have important implications for the future development of the Systems Engineering program at Corporación Universitaria Americana. The identified gaps suggest that curricular relevance cannot be addressed exclusively through incremental modifications or the incorporation of isolated courses. Rather, the results point to the need for a structural, continuous approach to curriculum development in which emerging technological demands, professional competencies, pedagogical strategies, and external stakeholder expectations are systematically articulated. This implication is particularly relevant for an institution seeking to strengthen its position in engineering education and consolidate its contribution to regional and national digital transformation.

From a curricular perspective, the first implication concerns the transition towards an integrative competency-based curriculum. The analysis indicates that the main challenge is not necessarily the absence of technological content, but how knowledge is organized, connected, updated, and translated into learning outcomes. Consequently, curriculum review should consider not only the sequence and content of courses but also how competencies are articulated across the program. This would allow traditionally separated areas, such as programming, databases, infrastructure, cybersecurity, and technology management, to converge around complex problems and authentic technological challenges. This approach aligns with recent evidence that engineering education increasingly requires integrating technical, analytical, methodological, social, and adaptive competencies rather than isolated disciplinary knowledge.

A second implication relates to the strategic incorporation of emerging technological domains. Artificial intelligence, data analytics, cybersecurity, cloud computing, distributed architectures, and intelligent systems should not be treated merely as optional or specialized components, but progressively integrated throughout the curriculum. This does not necessarily mean adding more courses; instead, it requires redefining learning outcomes and identifying where these competencies can be developed progressively across different stages of the program. Evidence from engineering and computing education shows that emerging areas such as AI security, cloud security, and advanced cybersecurity remain unevenly

incorporated into curricula, reinforcing the importance of systematic curriculum alignment rather than isolated technological additions.

This transformation also has pedagogical implications. The results support a shift from predominantly content-oriented teaching towards learning experiences centered on project-based learning, complex problem solving, experimentation, simulation, and real-world technological challenges. Programming education, for example, could increasingly incorporate data analysis, automation, intelligent applications, and software architecture, while technology management could integrate data-driven decision-making and digital project management. The objective would be to enable students to apply knowledge across contexts rather than demonstrate mastery of individual technical subjects. Recent research similarly highlights active learning and the development of analytical, problem-solving, decision-making, collaborative, and adaptive competencies as important components of engineering education in the context of Industry 4.0.

A further implication concerns the relationship between the university and the productive sector. The findings indicate that industry engagement should move beyond conventional internship arrangements towards more systematic forms of curricular co-creation. Companies, technology clusters, professional organizations, and other external stakeholders could help identify competencies, validate learning outcomes, develop authentic projects, and periodically review emerging technological needs. Such mechanisms would establish a continuous feedback loop between the program and its environment, reducing the risk of curricular obsolescence. Recent studies likewise identify industry-validated competencies, practical learning, and sustained stakeholder relationships as mechanisms to strengthen employability and align academic training with professional requirements.

At the institutional level, these implications require mechanisms for continuous curricular monitoring. Given the rapid evolution of digital technologies, curriculum relevance should be understood as a dynamic condition rather than a characteristic achieved permanently through periodic formal revisions. The program would therefore benefit from systematic processes for monitoring technological trends, labor-market requirements, graduate trajectories, employer perceptions, and developments in professional competency

frameworks. This approach could provide evidence for timely curricular adjustments while preserving coherence with the institutional educational model and accreditation requirements.

Finally, the implications extend to graduate employability and Corporación Universitaria Americana's strategic positioning. A curriculum that integrates emerging technologies with systems thinking, interdisciplinary collaboration, communication, ethical decision-making, and practical problem-solving could strengthen graduates' capacity to participate in higher-value segments of the ICT sector. In this sense, curricular transformation should not be understood simply as an academic response to technological change, but as an institutional strategy for developing professionals capable of contributing to innovation and digital transformation. The study's main implication is the need to establish a flexible, integrative, and externally connected curricular model in which relevance is continuously evaluated through interaction among academic knowledge, technological evolution, productive-sector demands, and societal needs.

Limitations

This study has some limitations that should be considered when interpreting its findings. First, the analysis relies primarily on documentary and curricular evidence, which may not fully capture the perceptions of students, graduates, employers, and faculty regarding the program's relevance. Second, the rapidly evolving nature of digital technologies may cause some identified gaps and trends to change over time. Therefore, the findings should be understood as a contextual diagnosis of the program's current relevance rather than a definitive assessment, highlighting the need for continuous monitoring and periodic curricular evaluation.

Research Agenda

Future research should extend the present curricular relevance analysis through empirical and longitudinal approaches that allow for a more comprehensive understanding of the relationship between Systems Engineering education and the evolving technological and productive environment. First, future studies should incorporate the perspectives of students, graduates, faculty members, employers, and industry representatives to identify differences between perceived and required competencies and to validate the curricular gaps identified in this study. This would strengthen the feedback mechanisms between academia and the productive sector, which are particularly relevant in contexts of rapid technological transformation.

Second, longitudinal research is needed to monitor the evolution of emerging competencies in areas such as artificial intelligence, data analytics, cybersecurity, cloud computing, digital engineering, and model-based systems engineering. Such studies could determine which competencies become structurally relevant over time and how quickly academic programs respond to changes in professional practice. In this regard, future research could develop competency-mapping models that systematically compare curricular learning outcomes with labor-market requirements and professional competency frameworks.

Third, comparative studies of Systems Engineering programs across universities and national contexts could provide evidence on alternative curricular models, pedagogical strategies, and

mechanisms of university–industry collaboration. Particular attention should be given to project-based and interdisciplinary learning, curricular co-creation with industry, and integrating emerging technologies across the curriculum rather than through isolated courses. Finally, future research should evaluate the impact of curricular transformations on measurable outcomes, including graduate employability, technological competencies, academic performance, innovation capacity, and employer satisfaction. This line of research would allow the relevance model proposed in this study to evolve from a diagnostic framework into a continuous evidence-based mechanism for curricular improvement. This agenda would contribute not only to the ongoing transformation of the Systems Engineering program at Corporación Universitaria Americana, but also to the broader discussion of how higher education institutions can maintain curricular relevance in rapidly changing technological environments.

CONCLUSIONS

This study analyzed the curricular relevance of the Systems Engineering program at Corporación Universitaria Americana from regional, national, international, and prospective perspectives, identifying the degree of alignment between its curricular structure and the educational, technological, productive, and regulatory demands of its environment. The findings demonstrate that the program maintains a relevant foundation in established areas such as software development, computational problem solving, technological solutions, and project-based learning. However, this relevance is uneven and less consistent when evaluated against the rapid transformation of the technological and productive environment.

The gap analysis shows that the main challenge is not the complete absence of emerging technological content, but its limited and predominantly incremental incorporation into the curriculum. Areas such as artificial intelligence, data analytics, cybersecurity, cloud computing, software architecture, and intelligent systems require greater integration and progression throughout the educational process. Consequently, curricular relevance should be understood not simply as the presence of contemporary subjects, but as the program's capacity to articulate knowledge, competencies, methodologies, and learning outcomes around complex and changing technological problems.

At the regional and national levels, the findings reveal a persistent gap between the evolution of the ICT sector and the program's curricular response. Although the curriculum addresses several competencies demanded by the productive environment, its structure does not yet systematically reflect the growing importance of advanced digital technologies and high-value ICT activities. This suggests strengthening the program's relationship with the productive ecosystem through mechanisms that enable continuous identification and validation of emerging competency requirements. Previous research similarly emphasizes the importance of competency-based curricular models and systematic interaction between academic and industry perspectives in Systems Engineering education.

From an international and prospective perspective, the analysis indicates that transforming Systems Engineering education requires moving beyond discipline-specific technical training toward systems thinking, interdisciplinary collaboration, complex problem solving, digital competencies, and the capacity to integrate technological solutions in diverse contexts. This is consistent with international perspectives that emphasize practical learning, multidisciplinary integration, continuous updating of methods and tools, and the development of competencies for addressing complex socio-technical systems.

Therefore, the study's main conclusion is that the curricular relevance of the Systems Engineering program should be conceived as a dynamic, continuous process rather than a condition achieved through periodic curricular revisions. The program has a solid foundation, but strengthening its relevance requires a more flexible, integrative curricular model that connects emerging technologies, transversal competencies, real-world projects, interdisciplinary learning, and systematic interaction with the productive sector. Such transformation would strengthen the graduate profile, improve responsiveness to labor-market demands, and position Corporación Universitaria Americana as an active contributor to regional and national digital transformation.

Finally, the study concludes that maintaining curricular relevance requires an institutional mechanism to continuously monitor technological trends, professional competencies, labor-market demands, graduate trajectories, and stakeholder expectations. In this sense, the findings provide not only a diagnosis of the program's current state but also a basis for future curricular decision-making and quality-improvement processes. The proposed perspective may also serve as a reference for other higher education institutions seeking to align Systems Engineering education with rapidly changing technological, productive, and societal environments.

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