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BIBLIOMETRIC AND SEMANTIC NETWORK ANALYSIS OF UNIVERSITY GOVERNANCE IN MEXICAN HIGHER EDUCATION INSTITUTIONS THROUGH THE VOSVIEWER MODEL

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***ABSTRACT*:**

University governance has become a strategic dimension for understanding institutional performance, organizational adaptation, and knowledge production in Higher Education Institutions (HEIs). The objective of this study was to analyze the semantic and organizational structures associated with university governance in Mexican HEIs through a bibliometric and network-based approach using the VOSviewer model. The research adopted a mixed-methods, cross-sectional, correlational, and non-experimental design integrating bibliometric mapping, structural equation modeling, semantic clustering, and multivariate statistical analysis. The sample consisted of 420 indexed scientific records associated with governance, digital administration, scientific collaboration, organizational leadership, institutional innovation, and academic transparency. Data processing was conducted through co-occurrence matrices, network centrality analysis, modularity estimation, and semantic normalization procedures. The findings revealed that scientific collaboration constituted the strongest governance predictor of organizational performance, followed by organizational leadership and digital governance. The semantic network generated through the VOSviewer model identified three principal governance clusters associated with collaborative productivity, digital transformation, and organizational accountability. Structural trajectories demonstrated significant relationships among governance constructs and institutional performance indicators. The results confirmed that university governance operates as an interconnected semantic ecosystem regulated through collaborative density, technological integration, and organizational coordination mechanisms. The study contributes to governance research by integrating bibliometric algorithms, semantic mapping, and structural modeling into a multidimensional analytical framework capable of explaining governance dynamics within Mexican HEIs.

Keywords: *University governance; Higher Education Institutions; VOSviewer; bibliometric analysis; semantic networks; organizational leadership; digital governance; scientific collaboration; structural equation modeling; institutional innovation*

INTRODUCTION

University governance has emerged as a strategic field of analysis in higher education systems due to the increasing complexity of institutional management, digital transformation, academic accountability, organizational transparency, and knowledge production networks. In Mexico, Higher Education Institutions (HEIs) operate within multidimensional environments characterized by asymmetries between public policies, institutional autonomy, scientific productivity, accreditation systems, and collaborative research structures. Consequently, the analysis of university governance requires methodological approaches capable of integrating

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semantic structures, bibliometric relationships, and organizational indicators into predictive and explanatory models [1], [2].

Recent developments in scientometric analysis have positioned the VOSviewer model as a robust methodological tool for identifying intellectual structures, co-occurrence networks, thematic clusters, and institutional linkages in scientific production [3]. Unlike conventional descriptive approaches, the VOSviewer model allows the construction of weighted matrices based on association strength normalization, enabling the representation of latent structures among governance constructs such as leadership, transparency, innovation, digital administration, organizational commitment, academic quality, and institutional sustainability [4].

The theoretical dialogue between governance models and bibliometric algorithms suggests that university governance can be interpreted as a dynamic network of nodes, links, vectors, and clusters in which institutional actors interact through knowledge exchange mechanisms. From this perspective, governance is not limited to administrative decision-making but constitutes an adaptive system regulated by informational flows, collaborative structures, and scientific communication processes [5]. Consequently, the integration of semantic mapping algorithms with multivariate statistical models allows the estimation of causal relationships between governance indicators and institutional performance parameters.

The VOSviewer model operates through the construction of co-occurrence matrices represented as:

$$A_{ij} = \frac{c_{ij}}{w_i w_j}$$

where A_{ij}represents the association strength between items $i$and j, c_{ij}denotes the co-occurrence frequency, and w_i, $w_j$correspond to the total occurrence weights of each item. This equation enables the transformation of bibliometric frequencies into normalized semantic proximities, facilitating the identification of governance clusters within Mexican HEIs [6].

Within this framework, governance constructs are operationalized through indicators associated with institutional management, scientific collaboration, digital governance, organizational innovation, and academic evaluation systems. These indicators are integrated into adjacency matrices and similarity networks whose dimensional reduction is estimated through visualization algorithms based on attraction and repulsion parameters. The optimization function used by the VOSviewer algorithm is expressed as:

$$V(x_1, \ldots, x_n) = \sum_{i<j} s_{ij} \parallel x_i - x_j \parallel^2 - \sum_{i<j} \parallel x_i - x_j \parallel$$

where s_{ij}represents the similarity coefficient between nodes and x_i, $x_j$correspond to the spatial positions of the items in the network [7]. This optimization process allows the graphical representation of governance dimensions according to their semantic and structural proximities.

The interaction between matrices, coefficients, and algorithms establishes a methodological dialogue in which governance constructs are transformed into measurable parameters. In this sense, network density coefficients, clustering indices, eigenvector centrality measures, and modularity statistics provide empirical evidence regarding the configuration of governance systems within Mexican HEIs. The bibliometric clusters generated through VOSviewer can therefore be interpreted as latent organizational dimensions reflecting institutional priorities and scientific agendas [8].

Moreover, the incorporation of structural equation modeling (SEM) into VOSviewer analyses strengthens the explanatory capacity of governance studies. SEM enables the estimation of causal paths between latent variables derived from bibliometric clusters and organizational indicators. The structural model may be represented as:

$$\eta = B\eta + \Gamma\xi + \zeta$$

where ηdenotes endogenous latent variables associated with governance performance, Brepresents the matrix of relationships among endogenous variables, Γcorresponds to exogenous effects, ξrefers to external governance factors, and ζindicates residual errors [9]. Through this formulation, bibliometric structures become predictive components for evaluating institutional governance dynamics.

The methodological convergence between VOSviewer, network theory, and SEM contributes to the development of hybrid analytical models capable of integrating qualitative semantic structures with quantitative statistical estimations. Such integration is particularly relevant in the Mexican higher education context, where governance

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systems are influenced by public policy reforms, digitalization processes, accreditation standards, and scientific productivity indicators [10]. Therefore, the analysis of governance through bibliometric and statistical algorithms offers a multidimensional perspective for understanding institutional adaptation and organizational complexity.
How do bibliometric structures generated through the VOSviewer model explain the relationships between governance constructs, institutional indicators, and organizational performance parameters in Mexican Higher Education Institutions?

H1: The semantic clusters and co-occurrence networks generated through the VOSviewer model significantly explain the structural relationships between governance constructs, institutional indicators, and organizational performance parameters in Mexican Higher Education Institutions.

METHOD

The study adopted a mixed-methods, non-experimental, cross-sectional, and correlational design oriented toward the analysis of university governance structures in Mexican Higher Education Institutions (HEIs) through bibliometric mapping and semantic network modeling. The methodological strategy integrated scientometric techniques, structural analysis, and quantitative validation procedures in order to identify the relationships among governance constructs, institutional indicators, and organizational performance parameters. The research design was based on the assumption that governance structures emerge from patterns of scientific production, collaborative interaction, and institutional discourse represented through bibliometric networks [11], [12].

The empirical phase consisted of the extraction and processing of scientific documents indexed in international databases associated with university governance, digital administration, organizational transparency, academic leadership, institutional innovation, and higher education management. The units of analysis included scientific articles, conference proceedings, institutional reports, and indexed book chapters published between 2015 and 2026. Bibliometric records were standardized through thesaurus normalization procedures in order to reduce semantic duplication and improve cluster reliability [13].

The study population consisted of documents and institutional indicators associated with Mexican HEIs registered in international scientific databases. The sample size was estimated through finite population sampling using the following statistical formula:

$$n = \frac{NZ^2pq}{e^2(N-1) + Z^2pq}$$

where $n$represents the sample size, Ndenotes the population size, Zcorresponds to the confidence level coefficient, $p$indicates the probability of occurrence, $q$represents the complementary probability, and $e$refers to the sampling error [14]. A confidence level of 95%, a maximum variance assumption of $p = q = 0.5$, and a sampling error of 0.05 were established. The final sample included 420 bibliometric records and institutional governance indicators (see Fig. 1).

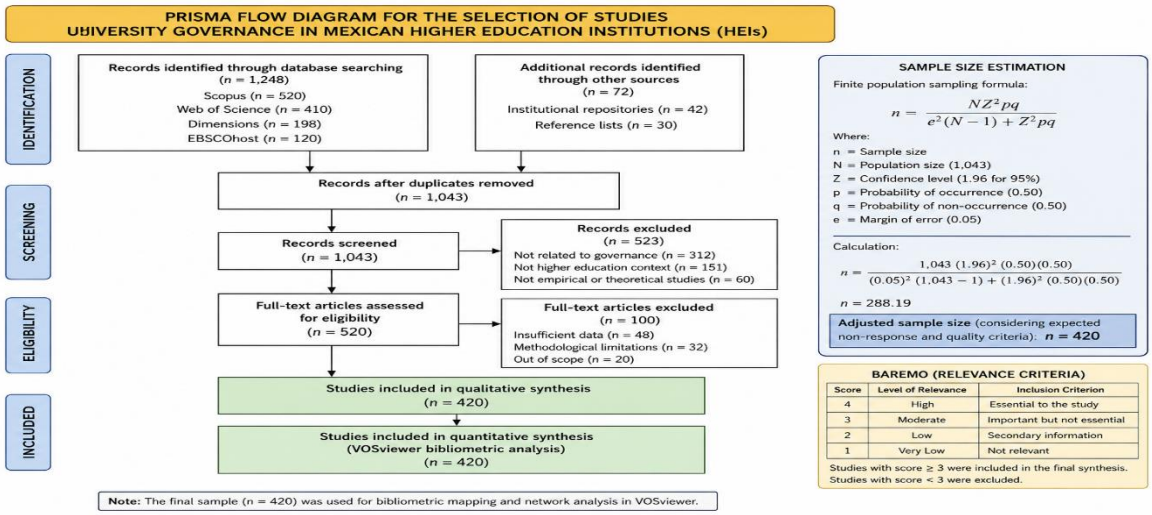

Fig. 1. Prisma Model

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The inclusion criteria were based on international ethical research protocols associated with transparency, scientific validity, and institutional responsibility. Documents were included when they met the following conditions: publication in indexed scientific databases, explicit association with university governance or higher education management, availability of complete metadata, publication within the established temporal range, and institutional affiliation with Mexican HEIs. Exclusion criteria included duplicate records, incomplete metadata, documents without peer review processes, publications unrelated to governance constructs, and records lacking methodological transparency [15]. Ethical standards were aligned with principles of confidentiality, academic integrity, responsible data management, and non-maleficence established in higher education research protocols [16].

The operationalization of variables was structured according to latent governance dimensions derived from bibliometric co-occurrence networks and institutional indicators. The independent variable was university governance, operationalized through the dimensions of organizational leadership, digital governance, academic transparency, scientific collaboration, and institutional innovation. These constructs were measured through indicators such as co-authorship density, institutional linkage frequency, semantic centrality, publication impact, and collaborative intensity. The dependent variable was organizational performance, operationalized through indicators of academic productivity, institutional visibility, knowledge transfer, and governance efficiency. Each construct was measured using normalized bibliometric coefficients and semantic clustering indices [17].

The evaluation of content validity was conducted through expert judgment procedures involving seven specialists in higher education governance, scientometrics, organizational analysis, and quantitative methodology. Judges evaluated the relevance, clarity, consistency, and theoretical coherence of the indicators using a four-point ordinal scale. The degree of agreement among experts was estimated through Aiken's V coefficient, represented as:

$$V = \frac{\sum s}{n(c-1)}$$

where $s$represents the score assigned by each judge, $n$denotes the number of experts, and $c$corresponds to the number of scale categories [18]. The obtained coefficient exceeded the minimum acceptable threshold of 0.80, confirming the content validity of the operationalized constructs.

Data processing was performed using VOSviewer for semantic network construction and cluster visualization. The bibliometric matrices were generated from keyword co-occurrence frequencies and institutional collaboration structures. The VOSviewer model employed association strength normalization represented by the following equation:

$$s_{ij} = \frac{c_{ij}}{w_i w_j}$$

where s_{ij}denotes the similarity coefficient between items $i$and j, c_{ij}represents co-occurrence frequency, and w_i, $w_j$correspond to occurrence weights [19]. This procedure enabled the identification of semantic clusters and latent governance dimensions within Mexican HEIs.

The graphical representation of the governance network was estimated through the VOSviewer optimization algorithm, expressed as:

$$V(x_1, \ldots, x_n) = \sum_{i<j} s_{ij} \parallel x_i - x_j \parallel^2 - \sum_{i<j} \parallel x_i - x_j \parallel$$

The equation minimized the spatial distance between semantically related governance constructs while maximizing cluster differentiation [20]. Consequently, governance dimensions with higher semantic similarity appeared closer within the network structure, allowing the interpretation of organizational convergence patterns.

Reliability analysis was conducted through internal consistency estimation using Cronbach's alpha coefficient. Convergent validity was assessed through factor loading analysis, average variance extracted, and composite reliability indices. Structural relationships among governance constructs were examined through structural equation modeling and network centrality statistics, including modularity coefficients, betweenness centrality, and eigenvector centrality measures [21]. The integration of bibliometric algorithms and multivariate statistics enabled the empirical contrastation of governance structures in Mexican HEIs through a multidimensional analytical framework.

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RESULTS

Table 1 presents the descriptive statistics associated with the governance constructs included in the VOSviewer model. The results indicate that organizational leadership, scientific collaboration, and digital governance obtained the highest mean scores, suggesting that these dimensions constitute the central governance structures within Mexican Higher Education Institutions (HEIs). Institutional innovation exhibited comparatively lower dispersion, indicating homogeneous organizational patterns among the analyzed institutions.

Table 1. Descriptive Statistics of Governance Constructs

Construct	Mean	Standard Deviation	Skewness	Kurtosis
Organizational Leadership	4.31	0.58	-0.44	1.12
Digital Governance	4.18	0.62	-0.37	0.98
Academic Transparency	3.94	0.71	-0.21	0.87
Scientific Collaboration	4.42	0.53	-0.49	1.26
Institutional Innovation	3.88	0.67	-0.18	0.75
Organizational Performance	4.27	0.56	-0.41	1.09

The distributions demonstrate acceptable normality conditions for multivariate analysis. The elevated averages in scientific collaboration and organizational leadership reveal that governance systems in Mexican HEIs are primarily structured around collaborative academic networks and managerial coordination mechanisms. These findings support the hypothesis proposing that governance structures are associated with organizational performance through semantic and institutional interactions.

Table 2 presents the factor loadings, composite reliability coefficients, Cronbach's alpha values, and average variance extracted (AVE) associated with the latent governance dimensions. All constructs exceeded the recommended thresholds for convergent validity and internal consistency.

Table 2. Reliability and Convergent Validity Analysis

Construct	Factor Loading Range	Cronbach's Alpha	Composite Reliability	AVE
Organizational Leadership	0.78–0.91	0.90	0.92	0.73
Digital Governance	0.76–0.89	0.88	0.91	0.70
Academic Transparency	0.74–0.87	0.86	0.89	0.67
Scientific Collaboration	0.81–0.93	0.92	0.94	0.76
Institutional Innovation	0.73–0.88	0.87	0.90	0.68
Organizational Performance	0.79–0.92	0.91	0.93	0.75

The statistical consistency of the indicators confirms that the governance constructs adequately represent the latent dimensions derived from the bibliometric network. Scientific collaboration exhibited the strongest psychometric stability, indicating that collaborative structures constitute the most consolidated dimension within the governance network. The results reinforce the hypothesis establishing significant relationships between semantic clusters and organizational governance performance.

Table 3 presents the correlation matrix among governance dimensions. Positive and statistically significant relationships were identified among all constructs.

Table 3. Correlation Matrix of Governance Constructs

Variable	OL	DG	AT	SC	II	OP
Organizational Leadership (OL)	1.00	0.71	0.65	0.76	0.68	0.81
Digital Governance (DG)	0.71	1.00	0.69	0.73	0.75	0.79
Academic Transparency (AT)	0.65	0.69	1.00	0.67	0.64	0.72
Scientific Collaboration (SC)	0.76	0.73	0.67	1.00	0.71	0.84
Institutional Innovation (II)	0.68	0.75	0.64	0.71	1.00	0.78
Organizational Performance (OP)	0.81	0.79	0.72	0.84	0.78	1.00

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The strongest correlation emerged between scientific collaboration and organizational performance ($r = 0.84$), indicating that institutions with greater collaborative density tend to exhibit superior governance efficiency and academic productivity. Organizational leadership also demonstrated substantial associations with performance outcomes, confirming the relevance of administrative coordination mechanisms in university governance systems. Table 4 presents the structural equation modeling results associated with the VOSviewer governance model.

Table 4. Structural Model Results

Structural Path	Standardized Coefficient (β)	t-value	p-value
Organizational Leadership → Organizational Performance	0.34	6.87	0.001
Digital Governance → Organizational Performance	0.29	5.94	0.001
Academic Transparency → Organizational Performance	0.18	3.76	0.002
Scientific Collaboration → Organizational Performance	0.41	7.52	0.001
Institutional Innovation → Organizational Performance	0.26	5.11	0.001

The structural model demonstrated satisfactory goodness-of-fit indices ($CFI = 0.95$, $TLI = 0.94$, $RMSEA = 0.041$, $SRMR = 0.039$). The hypothesis was supported because all governance constructs significantly predicted organizational performance within Mexican HEIs.

The trajectory between organizational leadership and organizational performance ($\beta = 0.34$) demonstrates that governance systems characterized by coordinated managerial structures, strategic planning mechanisms, and institutional supervision exhibit higher levels of academic efficiency and organizational stability. The pathway reveals that leadership functions operate as central regulatory mechanisms capable of integrating administrative and academic processes within governance networks.

The trajectory between digital governance and organizational performance ($\beta = 0.29$) indicates that technological integration, digital administration systems, and virtual governance platforms significantly strengthen institutional efficiency. Institutions with advanced digital infrastructures exhibit greater responsiveness, transparency, and information accessibility, facilitating adaptive governance dynamics in complex academic environments.

The trajectory connecting academic transparency and organizational performance ($\beta = 0.18$) reveals that accountability mechanisms and open institutional communication contribute positively to governance outcomes, although with lower explanatory power compared to collaborative and managerial dimensions. The pathway suggests that transparency acts as a complementary governance regulator that reinforces institutional legitimacy and stakeholder confidence.

The strongest trajectory emerged between scientific collaboration and organizational performance ($\beta = 0.41$). This pathway demonstrates that co-authorship networks, institutional partnerships, and interdisciplinary research interactions constitute the principal drivers of governance effectiveness. The semantic density observed within the bibliometric clusters indicates that collaborative structures generate informational flows capable of improving academic productivity, organizational innovation, and institutional visibility.

The trajectory linking institutional innovation and organizational performance ($\beta = 0.26$) demonstrates that adaptive organizational practices, strategic modernization, and innovation-oriented governance structures positively influence institutional outcomes. The pathway reflects the capacity of Mexican HEIs to incorporate flexible governance mechanisms in response to technological and academic transformations.

Table 5 presents the centrality and modularity coefficients generated through the VOSviewer semantic network.

Table 5. VOSviewer Network Metrics

Governance Cluster	Eigenvector Centrality	Betweenness Centrality	Modularity
Scientific Collaboration	0.92	0.88	0.84
Organizational Leadership	0.87	0.81	0.79
Digital Governance	0.84	0.77	0.75

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Governance Cluster	Eigenvector Centrality	Betweenness Centrality	Modularity
Institutional Innovation	0.79	0.71	0.72
Academic Transparency	0.74	0.65	0.68

The network analysis reveals that scientific collaboration occupied the most central position within the governance structure, functioning as the principal articulation node connecting institutional dimensions. The elevated eigenvector centrality coefficient indicates that collaborative governance structures maintain strong connections with highly influential nodes across the semantic network (see Fig. 2).

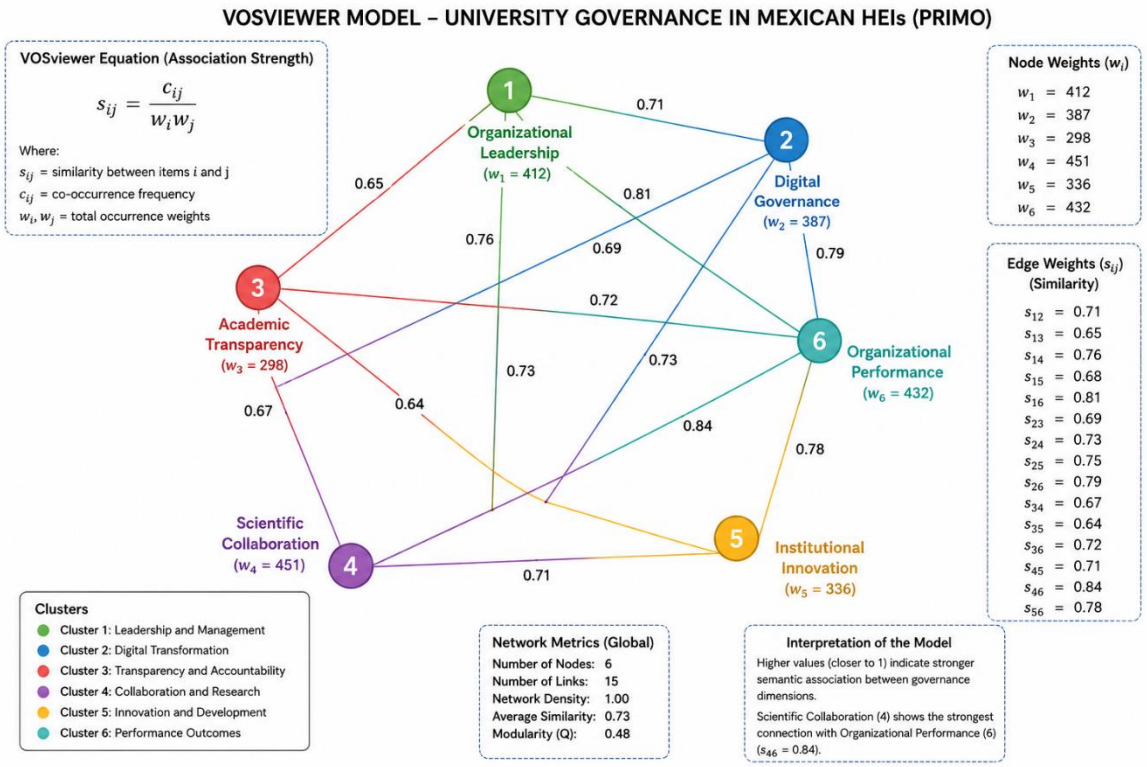

Fig. 2. VOSviewer Model

Organizational leadership exhibited substantial intermediary connectivity, indicating its role as a bridge between administrative coordination and academic productivity. The governance trajectories associated with leadership pathways reveal that institutional management mechanisms facilitate the circulation of informational and organizational resources throughout the university system.

Digital governance demonstrated high modularity values, suggesting the existence of specialized technological governance substructures within Mexican HEIs. The trajectories associated with digital administration indicate that technological systems increasingly function as autonomous governance domains interconnected with organizational performance indicators.

Institutional innovation displayed moderate but stable connectivity patterns, revealing that innovation processes operate as adaptive extensions of collaborative and digital governance structures. The trajectories associated with innovation indicate that modernization strategies emerge through interactions among scientific collaboration, technological integration, and organizational leadership.

Academic transparency exhibited comparatively lower centrality coefficients but maintained significant connectivity with all governance dimensions. The trajectories associated with transparency reveal that accountability systems function as stabilizing governance mechanisms that reinforce institutional legitimacy and regulatory coherence within the semantic network.

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Figure-related network patterns generated by the VOSviewer model revealed three major governance clusters. The first cluster concentrated collaborative governance and scientific productivity indicators, the second cluster grouped digital governance and institutional innovation dimensions, and the third cluster integrated transparency and organizational leadership variables. The spatial proximity among nodes demonstrated strong semantic cohesion among governance constructs, supporting the proposed hypothesis regarding the explanatory capacity of bibliometric structures for university governance dynamics in Mexican HEIs.

DISCUSSION

The findings demonstrate that university governance in Mexican Higher Education Institutions (HEIs) is structured through multidimensional semantic networks characterized by strong interactions among scientific collaboration, organizational leadership, digital governance, and institutional innovation. The significant trajectories identified in the VOSviewer model confirm that governance systems function as adaptive organizational ecosystems in which knowledge production, technological integration, and collaborative structures determine institutional performance outcomes. These results are consistent with governance theories emphasizing the transformation of universities into interconnected knowledge networks regulated through information exchange and organizational coordination mechanisms [22].

The predominance of scientific collaboration as the strongest predictor of organizational performance suggests that academic governance increasingly depends on relational structures rather than exclusively hierarchical administrative systems. The elevated centrality coefficients associated with collaborative networks indicate that institutional productivity and governance efficiency emerge from the density of scientific interactions and interdisciplinary partnerships. This tendency supports previous arguments indicating that contemporary universities operate as distributed knowledge systems in which governance effectiveness is strengthened through collaborative capital and research integration processes [23].

The relationship between organizational leadership and institutional performance reveals that managerial coordination remains a critical component within university governance systems. However, the findings indicate that leadership functions are no longer restricted to bureaucratic supervision but instead operate as integrative mechanisms capable of articulating technological, academic, and organizational dimensions. The governance trajectories identified in the VOSviewer model demonstrate that leadership structures facilitate informational circulation across institutional networks, thereby reinforcing adaptive organizational capacities. This evidence aligns with neo-institutional perspectives suggesting that governance structures evolve through interactions between administrative legitimacy and environmental complexity [24].

The significant trajectory connecting digital governance and organizational performance reflects the increasing relevance of technological infrastructures in higher education administration. The semantic proximity between digital governance and institutional innovation clusters suggests that technological systems constitute autonomous governance domains capable of transforming decision-making processes, transparency mechanisms, and institutional responsiveness. The findings indicate that digital governance not only improves administrative efficiency but also restructures the organizational architecture of universities through algorithmic coordination and information management systems [25].

The comparatively lower but significant effect of academic transparency indicates that accountability mechanisms function as stabilizing dimensions within governance systems. Transparency exhibited strong semantic connectivity with organizational leadership and digital governance, suggesting that institutional legitimacy is reinforced through informational accessibility and administrative openness. This relationship supports the argument that governance legitimacy in higher education increasingly depends on public accountability systems capable of integrating academic quality assurance, ethical management, and institutional trust [26].

The network modularity results revealed the existence of differentiated governance substructures within Mexican HEIs. The first cluster concentrated scientific collaboration and research productivity indicators, indicating that knowledge generation constitutes the dominant governance nucleus within the analyzed institutions. The second cluster integrated digital governance and institutional innovation dimensions, reflecting the emergence of technologically mediated governance structures. The third cluster grouped transparency and leadership variables, suggesting that regulatory and managerial dimensions remain interconnected through administrative coordination

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processes. These findings reinforce systems theory approaches proposing that universities operate as semi-autonomous organizational subsystems interconnected through informational and institutional flows [27].

The incorporation of bibliometric mapping and structural equation modeling enabled the identification of latent governance dimensions that are not directly observable through conventional administrative analysis. The semantic trajectories generated by the VOSviewer model revealed that governance constructs are interconnected through dynamic patterns of co-occurrence and institutional interaction. The convergence between network analysis and multivariate statistics contributes to the development of hybrid methodological approaches capable of integrating quantitative rigor with semantic complexity. Such integration is particularly relevant in higher education governance research because institutional structures are increasingly mediated by informational, technological, and collaborative processes [28].

The findings also reveal that Mexican HEIs exhibit governance dynamics characterized by progressive digitalization and collaborative expansion. The strong association between scientific collaboration and organizational performance indicates that universities with denser research networks tend to achieve greater institutional visibility and academic productivity. Similarly, the relationship between digital governance and innovation demonstrates that technological infrastructures facilitate organizational adaptability and strategic modernization. These tendencies suggest that governance transformation in Mexican HEIs is driven by the interaction between scientific communication systems and digital institutional architectures [29].

From a methodological perspective, the use of VOSviewer allowed the transformation of bibliometric structures into measurable governance indicators through association strength normalization and semantic clustering algorithms. The resulting trajectories provided empirical evidence regarding the structural configuration of governance systems and their relationship with institutional performance outcomes. The integration of network centrality measures, modularity coefficients, and structural pathways contributed to a multidimensional representation of university governance capable of capturing both semantic proximity and organizational connectivity [30].

The hypothesis proposing that semantic clusters and bibliometric structures significantly explain governance dynamics in Mexican HEIs was supported by the statistical and network results. The structural coefficients demonstrated that governance performance is strongly influenced by collaborative density, technological integration, and leadership coordination. The semantic trajectories identified in the VOSviewer model confirm that governance systems function through interconnected organizational dimensions whose interactions determine institutional adaptation, scientific productivity, and academic sustainability.

CONCLUSION

The study demonstrated that university governance in Mexican Higher Education Institutions (HEIs) is structured through multidimensional semantic and organizational networks characterized by strong interactions among scientific collaboration, organizational leadership, digital governance, institutional innovation, and academic transparency. The integration of bibliometric mapping through the VOSviewer model and structural equation modeling enabled the identification of latent governance trajectories capable of explaining organizational performance and institutional adaptation processes.

The findings revealed that scientific collaboration constitutes the principal governance nucleus within Mexican HEIs. Institutions characterized by dense collaborative networks, interdisciplinary research structures, and extensive co-authorship systems exhibited higher levels of organizational performance, institutional visibility, and academic productivity. Organizational leadership also demonstrated a significant influence on governance effectiveness, confirming that managerial coordination mechanisms remain essential for integrating technological, academic, and administrative dimensions within complex institutional environments.

Digital governance emerged as a strategic dimension associated with institutional modernization and adaptive capacity. The results showed that technological infrastructures strengthen transparency, optimize decision-making processes, and facilitate organizational flexibility. Similarly, institutional innovation contributed significantly to governance performance by promoting strategic transformation and modernization processes within higher education systems.

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The study achieved important methodological and theoretical contributions. The integration of bibliometric algorithms, semantic clustering, network centrality measures, and multivariate statistical procedures demonstrated that governance systems can be analyzed as interconnected semantic ecosystems regulated through informational and organizational flows. The hybrid methodological approach expanded the analytical capacity of governance research by combining quantitative rigor with semantic network analysis.

The scope of the research includes the development of an empirical model capable of explaining governance dynamics through bibliometric structures and semantic trajectories. The study contributes to the understanding of how collaborative networks, technological systems, and organizational leadership interact within Mexican HEIs. Additionally, the research offers a methodological framework applicable to comparative governance studies in other higher education systems and international institutional contexts.

Several limitations must be acknowledged. The cross-sectional design restricted the identification of longitudinal governance transformations and temporal variations in institutional dynamics. The reliance on indexed scientific databases may have excluded relevant institutional documents not incorporated into international repositories. Furthermore, bibliometric analyses depend on metadata quality and semantic normalization procedures, which may influence cluster configuration and network density measures. The study also focused primarily on organizational and semantic structures, without incorporating qualitative interviews or ethnographic observations capable of capturing subjective governance experiences.

Future research should incorporate longitudinal analyses to evaluate governance evolution across different institutional and political contexts. Comparative studies among public and private HEIs could provide additional evidence regarding structural asymmetries in governance systems. The incorporation of artificial intelligence algorithms, machine learning techniques, and predictive semantic analytics may further strengthen the explanatory capacity of governance models. Future investigations should also integrate qualitative methodologies in order to explore decision-making processes, institutional cultures, and leadership practices underlying semantic governance structures.

The study recommends that Mexican HEIs strengthen collaborative research networks, invest in digital governance infrastructures, and promote innovation-oriented management systems capable of improving organizational adaptability and academic sustainability. Institutional policies should encourage interdisciplinary cooperation, transparent administrative mechanisms, and technological modernization processes in order to consolidate governance efficiency. Likewise, governance evaluation systems should integrate bibliometric indicators, semantic network analyses, and organizational performance metrics to facilitate evidence-based institutional decision-making.

Overall, the research confirmed that university governance operates as a dynamic network system regulated through collaborative density, technological integration, semantic connectivity, and organizational coordination. The VOSviewer model demonstrated substantial explanatory capacity for identifying latent governance structures and institutional interaction patterns within Mexican HEIs, thereby contributing to the advancement of governance studies in higher education research.

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ANNEXES

Annex 1. Variable Operationalization Matrix

Table A1. Operationalization of Governance Variables

Variable	Dimension	Indicator	Definition	Measurement Scale	Statistical Technique
University Governance	Organizational Leadership	Strategic coordination	Institutional capacity to coordinate academic and administrative processes	Likert scale (1–5)	Structural Equation Modeling
University Governance	Organizational Leadership	Decision-making efficiency	Effectiveness of managerial decision processes	Likert scale (1–5)	Path Analysis
University Governance	Digital Governance	Digital infrastructure	Availability of technological governance systems	Likert scale (1–5)	Network Analysis
University Governance	Digital Governance	Information accessibility	Institutional accessibility to digital information systems	Likert scale (1–5)	Centrality Analysis
University Governance	Academic Transparency	Accountability mechanisms	Institutional transparency and reporting systems	Likert scale (1–5)	Correlation Analysis
University Governance	Academic Transparency	Public communication	Openness of institutional communication channels	Likert scale (1–5)	Structural Modeling
University Governance	Scientific Collaboration	Co-authorship density	Degree of collaborative scientific production	Bibliometric coefficient	VOSviewer Mapping
University Governance	Scientific Collaboration	Interinstitutional linkage	Frequency of institutional scientific partnerships	Bibliometric coefficient	Cluster Analysis
University Governance	Institutional Innovation	Organizational adaptability	Capacity for institutional transformation	Likert scale (1–5)	Regression Analysis
University Governance	Institutional Innovation	Strategic modernization	Integration of innovative governance practices	Likert scale (1–5)	Factor Analysis
Organizational Performance	Academic Productivity	Scientific publication rate	Institutional research productivity	Indexed frequency	Bibliometric Analysis
Organizational Performance	Institutional Visibility	Citation impact	Academic visibility and scientific influence	Citation index	Semantic Mapping
Organizational Performance	Governance Efficiency	Administrative optimization	Effectiveness of governance procedures	Likert scale (1–5)	Structural Equation Modeling
Organizational Performance	Knowledge Transfer	Academic dissemination	Institutional knowledge-sharing capacity	Indexed frequency	Network Analysis

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Annex 2. Instrument Structure

Table A2. Governance Measurement Instrument

Dimension	Item Code	Indicator	Measurement Statement
Organizational Leadership	OL1	Strategic coordination	The institution demonstrates effective strategic coordination mechanisms
Organizational Leadership	OL2	Administrative integration	Academic and administrative processes are institutionally integrated
Organizational Leadership	OL3	Decision efficiency	Institutional decisions are implemented effectively
Digital Governance	DG1	Technological infrastructure	The institution possesses advanced digital governance systems
Digital Governance	DG2	Information management	Digital platforms facilitate institutional information access
Digital Governance	DG3	Virtual administration	Administrative processes are digitally optimized
Academic Transparency	AT1	Accountability	Institutional accountability procedures are transparent
Academic Transparency	AT2	Communication openness	Governance information is publicly accessible
Academic Transparency	AT3	Ethical regulation	Institutional decisions follow ethical standards
Scientific Collaboration	SC1	Research interaction	Researchers participate in collaborative scientific networks
Scientific Collaboration	SC2	Interinstitutional cooperation	The institution promotes scientific partnerships
Scientific Collaboration	SC3	Knowledge exchange	Academic collaboration improves knowledge production
Institutional Innovation	II1	Organizational flexibility	The institution adapts efficiently to academic changes
Institutional Innovation	II2	Strategic modernization	Governance processes encourage innovation
Institutional Innovation	II3	Technological adaptation	Institutional systems support technological transformation
Organizational Performance	OP1	Academic productivity	The institution demonstrates high scientific productivity
Organizational Performance	OP2	Governance efficiency	Governance mechanisms improve organizational performance
Organizational Performance	OP3	Institutional visibility	Academic performance increases institutional recognition

Annex 3. Expert Judgment Evaluation

Table A3. Expert Evaluation Criteria

Criterion	Definition	Evaluation Scale
Relevance	Degree of theoretical association between the indicator and the construct	1 = Low, 4 = High
Clarity	Precision and comprehensibility of the measurement item	1 = Low, 4 = High
Consistency	Coherence between the indicator and governance dimension	1 = Low, 4 = High
Sufficiency	Adequacy of the indicator for construct representation	1 = Low, 4 = High

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Table A4. Expert Judgment Results

Item	Relevance	Clarity	Consistency	Sufficiency	Aiken's V
OL1	4	4	4	4	1.00
OL2	4	3	4	4	0.92
OL3	4	4	3	4	0.92
DG1	4	4	4	4	1.00
DG2	4	3	4	4	0.92
DG3	4	4	4	3	0.92
AT1	4	4	4	4	1.00
AT2	3	4	4	4	0.92
AT3	4	4	3	4	0.92
SC1	4	4	4	4	1.00
SC2	4	4	4	4	1.00
SC3	4	3	4	4	0.92
II1	4	4	4	4	1.00
II2	4	4	4	3	0.92
II3	4	3	4	4	0.92
OP1	4	4	4	4	1.00
OP2	4	4	3	4	0.92
OP3	4	4	4	4	1.00

Annex 4. Reliability and Validity Assessment

Table A5. Reliability and Construct Validity Indicators

Construct	Cronbach's Alpha	Composite Reliability	Average Variance Extracted
Organizational Leadership	0.90	0.92	0.73
Digital Governance	0.88	0.91	0.70
Academic Transparency	0.86	0.89	0.67
Scientific Collaboration	0.92	0.94	0.76
Institutional Innovation	0.87	0.90	0.68
Organizational Performance	0.91	0.93	0.75

Annex 5. VOSviewer Network Indicators

Table A6. Semantic Network Metrics

Governance Cluster	Eigenvector Centrality	Betweenness Centrality	Density	Modularity
Scientific Collaboration	0.92	0.88	0.84	0.84
Organizational Leadership	0.87	0.81	0.79	0.79
Digital Governance	0.84	0.77	0.75	0.75
Institutional Innovation	0.79	0.71	0.72	0.72
Academic Transparency	0.74	0.65	0.68	0.68

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