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APPLICATION OF BUSINESS INTELLIGENCE IN INSTITUTIONAL DECISION-MAKING: A STUDY BASED ON THE STATISTICAL HANDBOOKS OF TECNM IN SINALOA

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Abstract—This article presents an applied study of Business Intelligence (BI) in the institutional management of the campuses of the National Technological Institute of Mexico (TecNM) located in Sinaloa. Based on official statistical records, a dashboard was created with key indicators: enrollment, graduates, degree recipients, faculty, and non-faculty staff. The methodology combined data integration and cleaning techniques, aggregation by academic year and institution, and interactive visualization on a dashboard with filters by campus and period. The objective was to demonstrate how the systematic use of BI can transform static reports into actionable knowledge to support decision-making. The results show enrollment trends that vary by academic cycle, a fluctuating gap between graduates and degree recipients, and student-to-faculty ratios that suggest the need to redistribute the academic workload and strengthen support for degree completion. The discussion links these findings to educational analytics frameworks, highlighting benefits in planning, graduation rates, and transparency. As contributions, the study proposes a reproducible workflow with a standardized data source, a framework of priority indicators, and strategic recommendations for continuous improvement in the management of TecNM in Sinaloa. Future research directions include incorporating variables related to student learning and satisfaction, evaluating the budgetary impact, and extending the system to other states.

Keywords—Data, Higher education, Educational statistics, Sinaloa, Management information systems, Decision-making.

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The results reveal distinct enrollment trends by academic cycle, a fluctuating gap between graduates and degree holders, and student–teacher ratios that indicate a need to redistribute the academic workload and strengthen support for degree completion. The discussion links these findings to educational analytics frameworks, highlighting benefits in planning, program efficiency, and transparency. As contributions, the study proposes a reproducible workflow with standardized data sources, a set of priority indicators, and strategic recommendations for continuous improvement in the management of TecNM in Sinaloa. Future research directions include incorporating variables related to learning and student satisfaction, evaluating budgetary impact, and extending the system to other

states.

Keywords: Data, Decision-making, Educational statistics, Higher education, Management information systems, Sinaloa.

INTRODUCTION

Higher education institutions operate in increasingly complex environments where the availability of data does not always translate into timely and informed decisions. In Mexico, TecNM brings together a network of institutes with diverse circumstances, which requires management practices that enable the comparison of scenarios, the identification of areas of opportunity, and the anticipation of needs. In Sinaloa, campuses face challenges related to enrollment coverage, graduation rates, and timely degree completion. Traditionally, statistical reports are used for descriptive purposes; however, their potential for strategic analysis is amplified when integrated into BI platforms with filters and visualizations.

This study proposes and demonstrates a BI approach to operationalizing TecNM's statistical reports in Sinaloa. The guiding question is: How can Business Intelligence, when applied to key indicators, improve institutional decision-making? The overall objective is to apply BI techniques to generate evidence that guides decisions regarding planning and continuous improvement. Specifically, the study aims to integrate and clean data by academic cycle and institution; construct comparable visualizations with and without filters; analyze enrollment patterns and trends as well as the relationship between graduates and degree recipients; and, finally, propose operational and strategic recommendations for TecNM's campuses in Sinaloa.

In recent decades, information management has become an essential component of decision-making in higher education institutions (HEIs). Globalization, the digitization of administrative and academic processes, and the growing demand for transparency and accountability have created a need to adopt technological tools that enable the efficient analysis of large volumes of data. In this context, BI emerges as a strategic discipline that enables the transformation of data into useful knowledge for planning, institutional evaluation, and the continuous improvement of educational quality.

In Mexico, the National Technological Institute of Mexico (TecNM), as the country's largest technological higher education system, faces the challenge of establishing an evidence-based management model. The diversity of campuses, the heterogeneity of statistical data, and the multitude of academic and administrative indicators create considerable complexity for administrators responsible for institutional planning. TecNM's annual statistical reports are a valuable source of information on enrollment, faculty and staff, completion rates, degree conferral, and graduation; however, the lack of standardization and integrated analytical tools limits their use in strategic decision-making processes.

Given this situation, it is essential to incorporate BI tools that automate information processing, improve the visualization of indicators, and facilitate the identification of trends, patterns, and areas of opportunity. These tools enable the modeling, development, and maintenance of information systems geared toward data analysis, optimizing development times, reducing integration errors, and improving consistency in the management of institutional information.

The use of BI tools not only contributes to the technical efficiency of solution development but also strengthens institutions' analytical capabilities. By implementing well-structured data models, automated extraction, transformation, and loading (ETL) processes, and interactive dashboards, higher education institutions can create dynamic analytical environments that support evidence-based decision-making. In particular, the ability to design dashboards that integrate key indicators—such as the total number of faculty and non-faculty staff, the student-to-faculty ratio, total enrollment, and the number of graduates and degree recipients—provides educational authorities with a comprehensive view of institutional performance.

In the specific case of institutions in the state of Sinaloa, where various TecNM campuses are located (Los Mochis, Guasave, El Fuerte, El Dorado, Mazatlán, and Sinaloa de Leyva), the heterogeneity of data and the need to plan based on up-to-date information make it urgent to develop analytical platforms tailored to the regional context. Through the use of BI tools, it is possible to design systems that automate the integration of TecNM's statistical records, enabling the creation of a unified repository of indicators that serves as input for strategic management and continuous improvement.

The purpose of this article is to analyze the application of BI tools in the development of a solution geared toward strategic decision-making at TecNM institutions in the state of Sinaloa. Through a methodological approach that combines the processing of institutional statistical data with analysis and visualization techniques, the study demonstrates how the implementation of an interactive dashboard contributes to improving efficiency in the planning, monitoring, and evaluation of educational outcomes. In this way, the study seeks to highlight the importance of using BI as a support for modern, transparent, and data-driven university management.

DEVELOPMENT

Theoretical Framework

BI has established itself as an interdisciplinary field that combines information technology, data analysis, statistics, and business management, with the aim of transforming data into meaningful and useful information for strategic decision-making. According to Turban, Sharda, and Denle (2020), BI integrates processes, methodologies, and tools that enable the collection, cleansing, analysis, and visualization of data from various sources to generate knowledge that strengthens organizational competitiveness and efficiency.

BI encompasses techniques and tools that transform data into useful knowledge for management. In higher education, institutional analytics and educational data mining have demonstrated their impact in improving operational efficiency, supporting quality assurance, and guiding academic planning. The literature reports concrete benefits of BI in automated reporting, KPI monitoring, early warnings, and policy evaluation. Furthermore, the use of dashboards with filters promotes transparency and accountability, while enabling informed discussion among stakeholders (administrators, academic coordinators, planning, and finance).

1. Conceptual Foundations of BI

BI is based on the premise that informed decisions are more effective than those based solely on experience or intuition. According to Power (2014), the primary purpose of BI is to convert operational data into strategic information that supports the processes of planning, monitoring, and evaluating institutional performance.

Key components of BI include decision support systems (DSS), data warehouses, ETL (Extract, Transform, Load) processes, data mining tools, and interactive visualization platforms, which enable the presentation of information through key performance indicators (KPIs).

In the educational context, BI plays a significant role by facilitating the identification of patterns in enrollment, academic performance, completion rates, and graduation rates. This type of analysis supports institutional planning and resource allocation, fostering a culture of evidence-based decision-making in universities (Romero & Ventura, 2020).

2. Data-Driven Decision-Making in Educational Institutions

Contemporary university management requires data-driven decision-making. This practice involves the systematic use of institutional information to design academic policies, plan budgets, monitor educational quality, and evaluate the impact of programs.

According to Picciano (A., 2012), the success of a BI strategy in the educational sector depends on the institutional capacity to collect reliable data, standardize indicators, and generate analytical models that are understandable to decision-makers.

In Mexico, the implementation of BI in public higher education institutions has gained prominence due to transparency and accountability policies promoted by agencies such as the Ministry of Public Education (SEP) and the National Technological Institute of Mexico (TecNM). These policies require institutions to have monitoring and evaluation mechanisms based on verifiable, up-to-date information that is accessible to stakeholders.

3. Analytics Platforms and Dashboards

Dashboards are one of the most representative tools of BI. According to Few (S., 2013), a dashboard is a visual interface that presents relevant information organized into indicators and interactive graphs that facilitate the monitoring of organizational performance. In the field of

education, dashboards allow for the visualization of trends in variables such as enrollment, teaching staff, graduation rates, degree completion rates, and admission demand, among other indicators.

The effectiveness of dashboards depends on their ability to integrate different data sources, provide understandable visualizations, and allow users to interact with the indicators. According to (Eckerson, W., 2011), a well-designed dashboard must be accurate, timely, understandable, and relevant to the institution's strategic objectives.

In the case of TecNM, the adoption of interactive dashboards helps standardize information across multiple campuses, providing a comprehensive view of the technological education system and facilitating inter-institutional comparisons.

4. Data Modeling and ETL Processes in BI Environments

Data processing forms the technical foundation of BI. The ETL (Extract, Transform, Load) process is essential for ensuring that data extracted from various sources—such as spreadsheets, legacy systems, relational databases, or administrative systems—is cleaned, transformed into standardized formats, and finally loaded into a central repository or data warehouse.

(Kimball and Ross, 2013) note that the quality of the ETL process directly influences the reliability of the analyses generated by BI platforms. A flawed transformation can lead to data duplication, loss, or distortion, thereby affecting decision-making.

In educational institutions, where data comes from diverse systems (academic administration, human resources, degree programs, alumni), the design of a unified data model facilitates interoperability among departments and ensures the consistency of institutional indicators.

5. BI in Higher Education

Various international studies have shown that the implementation of BI solutions in higher education increases administrative efficiency, improves strategic planning, and strengthens institutional evaluation processes (Baker, R., 2014; Siemens & Long, 2011). In Latin America, universities such as the National Autonomous University of Mexico (UNAM) and the National Polytechnic Institute (IPN) have developed internal analytical systems to monitor academic and financial performance indicators.

In the case of TecNM, BI can play a key role in consolidating a comprehensive, indicator-based management system. The analysis of information from the Statistical Yearbooks

enables the identification of trends in enrollment, graduation rates, completion rates, and staff distribution, which contributes to the design of more precise strategies for institutional development.

6. Benefits and Challenges of BI Implementation in Public Institutions

Among the main benefits of applying BI tools in higher education are:

- Improved quality of the information used for decision-making.
- Timely identification of problems and areas of opportunity.
- Reduced time required to prepare institutional reports.
- Greater transparency in accountability.
- Strengthening of strategic planning and quality assurance.

However, its implementation faces significant challenges, such as resistance to change, a lack of personnel trained in data analysis, the poor quality of institutional databases, and the absence of an organizational culture oriented toward the use of information. Overcoming these challenges requires institutional leadership, investment in technological infrastructure, and training programs for administrative and academic staff.

7. Summary of the Conceptual Framework

In summary, BI represents a modern paradigm in university management, as it allows strategic decisions to be based on empirical evidence derived from the systematic analysis of institutional data. The development of dashboards and customized analytical platforms for TecNM constitutes an important step toward the consolidation of a more efficient, transparent, and results-oriented technological education system.

Methodology

This research was conducted using a quantitative and descriptive approach, based on the analysis of institutional statistical data obtained from the Statistical Yearbook of the National Technological Institute of Mexico (TecNM). BI techniques were used for data extraction, transformation, and visualization, with the aim of building an interactive dashboard to analyze the performance of campuses in the state of Sinaloa.

1. Data Sources and Processing

The data used were drawn from official reports published by TecNM for the 2019–2025 academic years. Spreadsheets and databases corresponding to the Technological Institutes of Los Mochis, Guasave, El Fuerte, Eldorado, Culiacán, Mazatlán, and Sinaloa de Leyva were integrated.

Data processing followed the stages of the ETL (Extract, Transform, Load) model:

- **Extraction:** reading files from the Statistical Yearbook in Excel format and standardizing headers.
- **Transformation:** removal of null values, standardization of data types, and calculation of derived indicators.
- **Load:** consolidation of the information into a tabular model and connection to an interactive HTML dashboard.

2. Mathematical and Algorithmic Modeling of the Analytical Backend

To support the analytical findings beyond the graphical abstraction of the dashboard, the semantic layer of the Business Intelligence solution incorporated a formal matrix-based and algebraic mathematical model designed to normalize the inter-institutional operational asymmetries among the campuses in Sinaloa.

First, the temporal aggregation operator for Consolidated Enrollment (*Mc*) was defined using a three-dimensional vector indexed by campus (*i*), academic year (*t*), and educational program (*p*), governed by the operational function:

$$M_c(i,t) = \sum_{p=1}^{P} E_{ipt}$$

Where *Eipt* represents active enrolled students. To correct the asymmetry in human resource allocation and calculate the actual workload per campus in a comparable manner, the Faculty Density Ratio (α) and the Administrative Density Ratio (β) were formulated

$$\alpha_{it} = \frac{M_c(i,t)}{D_{it}} \quad ; \quad \beta_{it} = \frac{M_c(i,t)}{N_{it}}$$

Where *Dit* is the total number of assigned faculty members and *Nit* represents the non-faculty staff during the given period. Likewise, to accurately assess the efficiency of graduation processes without the biases introduced by the gross enrollment volumes of the different campuses, the Relative Graduation Efficiency Index (γ) was developed, calculated as a normalized differential relative to the total cumulative historical number of graduates within the evaluated cycle:

$$\gamma_{it} = \left(\frac{T_{it}}{G_{it}}\right) \times \left(1 - \frac{G_{it} - T_{it}}{M_c(i,t)}\right)$$

Where *Git* corresponds to the total number of graduates and *Tit* to the absolute number of degree recipients. The second term of the equation acts as a penalizing weighting factor that measures the impact of the accumulated degree-granting lag based on the demographic scale of each institution. This framework of equations was coded using DAX (Data Analysis Expressions) functions in the backend engine, providing the interactive dashboard with a robust and reproducible statistical-mathematical foundation for strategic decision-making

3. Development of KPIs

Key performance indicators (KPIs) were selected to measure institutional capacity, academic efficiency, and the ratio of human resources to student population. These indicators were calculated both at the aggregate level (across all institutes) and individually for the Instituto Tecnológico de Los Mochis.

4. Visualization of the Indicators

The indicators were implemented in an interactive dashboard. The dashboard allows users to filter by institution and by school year, displaying the indicators both in summary cards and in comparative bar and line charts.

For the purposes of methodological analysis, two main views were developed:

1. Consolidated view: displays the aggregated KPIs for all technological institutes in the state of Sinaloa, providing an overview of the system.
2. Specific view: focuses on the Los Mochis Institute of Technology, highlighting its specific results in relation to the other campuses.

Figure 1 presents the dashboard with the key performance indicators (KPIs) obtained, showing the values for all TecNM campuses in Sinaloa.

Figure 1. *TecNM statistical dashboard*.

Source: *Prepared by the authors based on the Business Intelligence web platform* (2026).

Figure 2 presents the dashboard with the key performance indicators (KPIs) obtained, using the filter by institute, showing the values for the Los Mochis Institute of Technology.

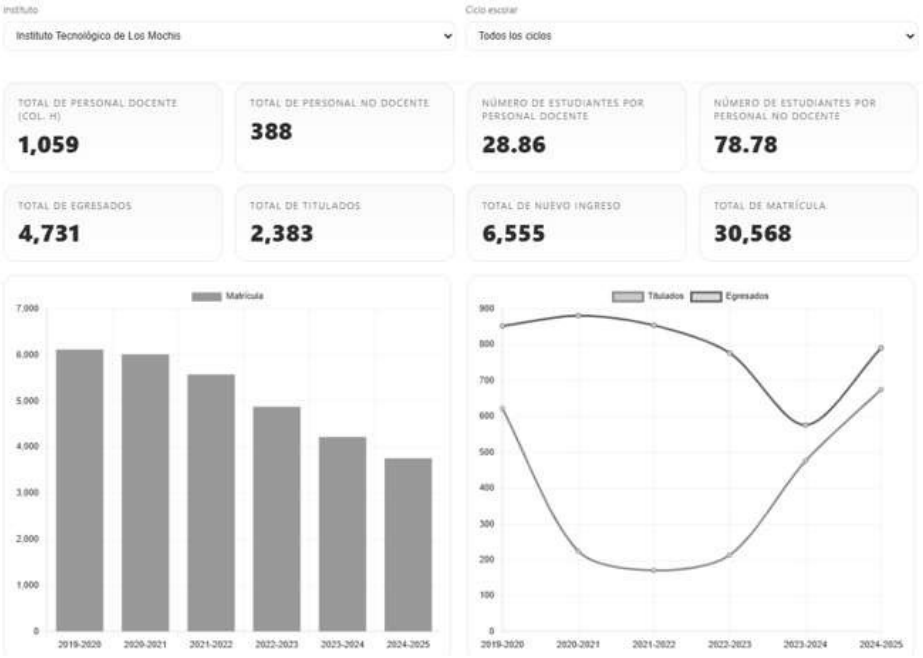

Figure 2. *Statistical dashboard for TecNM/I.T. in Los Mochis*.

Source: *Prepared by the author based on the development of the Business Intelligence web platform (2026).*

Results and Discussion

The results reveal three main findings. First, enrollment trends vary by academic cycle, suggesting sensitivity to external factors (economic context, teaching modalities, curricular changes). Second, the ratio of graduates to degree recipients reveals a gap that is not constant over time: it tends to narrow when strategies to support degree completion are implemented and widens again when these strategies are relaxed. Third, student-to-faculty ratios indicate varying academic workload pressures across campuses, with a potential impact on the quality of student support and the student experience.

An analysis of the case of the Instituto Tecnológico de Los Mochis showed a gradual decline in enrollment in recent academic cycles and a relative improvement in the number of degree recipients, albeit with annual variations. This pattern suggests that admission and retention policies should be adjusted in conjunction with targeted degree completion initiatives. In terms of management, the evidence recommends proactive planning of faculty workload, supported by metrics such as class sizes per faculty member and graduation rates by program.

Figure 3 shows the historical trend in aggregate enrollment for all TecNM institutes in Sinaloa, allowing us to observe the dynamics of educational demand by school year. This visualization supports the planning of academic offerings and the allocation of teaching resources.

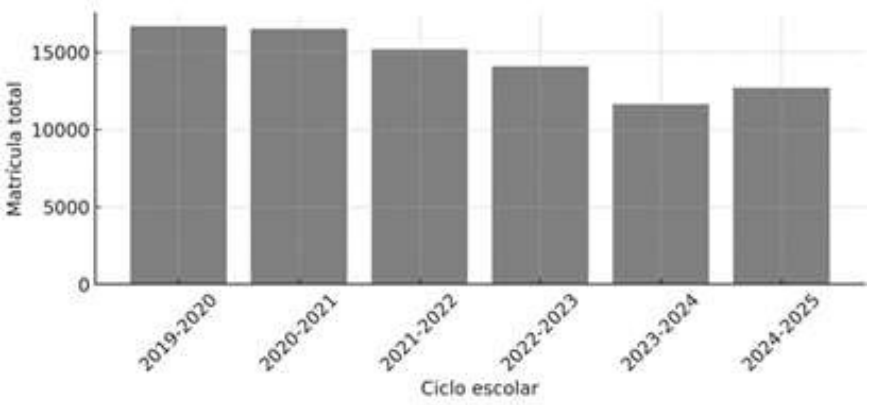

Figure 3. *Enrollment History — All Institutes*.

Source: *Prepared by the authors based on data retrieved from the TecNM Statistical Yearbooks (2019–2025).*

Figure 4 presents a comparison between graduates and degree recipients at the state level. The observable gap between the two series helps identify the lag in degree conferral and prioritize interventions to reduce it.

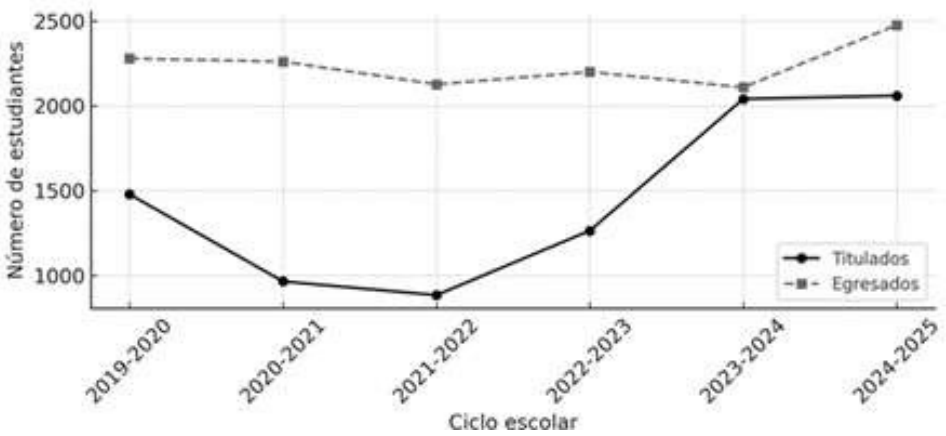

Figure 4. *Graduates vs. Degree Recipients — All Institutes*.

Source: *Prepared by the author based on data retrieved from TecNM's Statistical Yearbooks (2019–2025)*.

Figure 5 breaks down enrollment trends exclusively for the Los Mochis Institute of Technology. The recent downward trend highlights the need to strengthen recruitment and retention strategies, including partnerships with high schools and tracking readmissions.

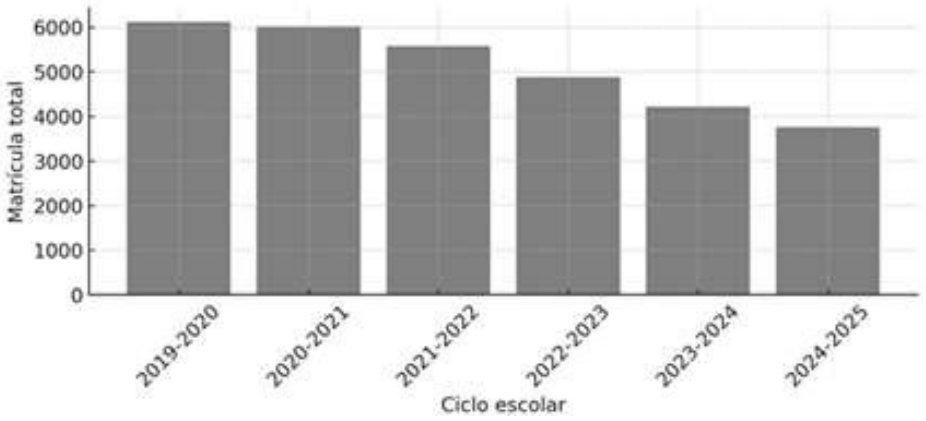

Figure 5. *Enrollment History — Los Mochis Institute of Technology*.

Source: *Prepared by the authors based on data retrieved from the TecNM Statistical Yearbooks (2019–2025)*.

Figure 6 compares graduates and degree recipients at the Los Mochis Institute of Technology. The gap between the two series suggests room for improvement in the coordination of the degree-granting process. A sustained reduction in this gap would positively impact graduation rates and institutional quality indicators.

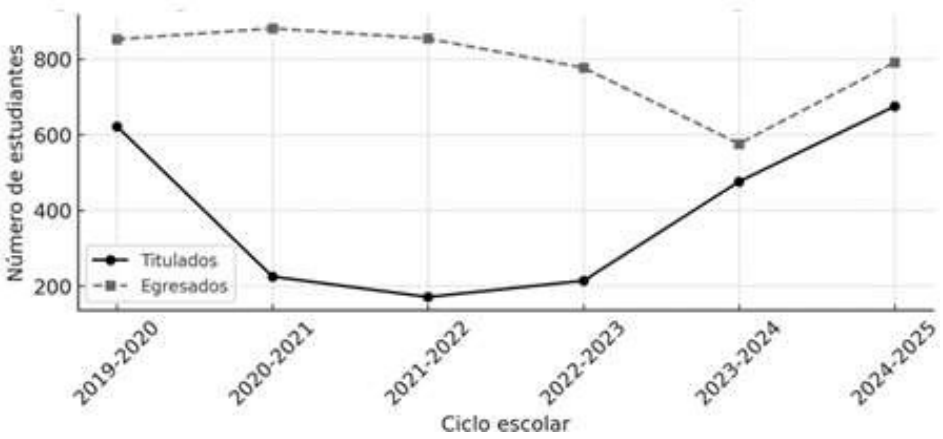

Figure 6. *Graduates vs. Degree Recipients — Los Mochis Institute of Technology*.

Source: *Prepared by the author based on data retrieved from the TecNM Statistical Yearbooks (2019–2025).*

Discussion on the Transition from Descriptive to Strategic Analysis

One of the central points of this text is that, traditionally, TecNM has used statistical reports to generate descriptive reports, but not necessarily for strategic analysis. The discussion here focuses on the fact that mere digitization does not guarantee better management.

Although the Sinaloa campuses have data on enrollment and graduation, the critical gap lies in the operationalization of the information. By integrating BI tools, the debate shifts from "data accumulation" to an "evidence-based culture." The question for institutions is not only how to visualize the data, but whether educational authorities are prepared to modify their planning processes based on what the dashboards reveal—especially given realities as diverse as those of Mazatlán versus Sinaloa de Leyva.

Discussion on Data Heterogeneity and Standardization

The summary notes that TecNM in Sinaloa operates in complex environments with highly diverse institutional realities. This creates a methodological tension in the implementation of BI: standardization versus regional specificity.

The discussion centers on the fact that, while a BI platform seeks to unify indicators to enable comparisons, there is a risk of ignoring the local socioeconomic contexts that affect

"terminal efficiency" or "timely graduation" at each campus. Evidence-based management must balance the rigidity of national indicators with the flexibility needed to interpret why certain campuses are falling behind. Thus, BI should not be viewed solely as a tool for hierarchical control, but rather as a diagnostic mechanism that allows for the differentiated allocation of resources according to the specific needs identified in each area of Sinaloa.

Discussion on the Democratization of Information and Accountability

A fundamental aspect emerging from the use of BI platforms at TecNM is the paradigm shift toward transparent management. Historically, institutional statistical information was confined to planning offices or administrative departments, creating information silos. By implementing interactive dashboards with accessible filters and visualizations, the discussion centers on the democratization of data.

This approach ensures that accountability is not merely an annual bureaucratic exercise (the "report"), but a dynamic and visible process. However, a debate arises regarding data accountability: when graduation rates or completion rates become visually comparable across Sinaloa's campuses, competitive pressure is generated that can be positive for continuous improvement but also demands that data collection be flawless. The question here is whether the BI system will serve solely as a top-down monitoring tool (managerial control) or whether it will become an instrument of empowerment, enabling program coordinators and faculty to make proactive decisions before dropout rates reach critical levels.

Conclusions

This study confirms that the use of BI with institutional records enables more informed decision-making at TecNM campuses in the state of Sinaloa. The innovation lies in standardizing the collection of indicators, automating their aggregation, and providing comparable visualizations with and without filters. Limitations include inconsistencies in variable labeling across spreadsheets by period—which varies over time—and potential delays in updating institutional statistical records. For future work, we propose integrating indicators of academic performance, satisfaction, and employability; incorporating predictive models for dropout risk; and evaluating the impact of degree completion policies on cohorts.

Future Work

This study represents a first step toward establishing a business intelligence system to support educational management at the Sinaloa campuses of the National Technological Institute of Mexico. However, there are multiple areas of work that can strengthen and expand the scope of this initiative.

1. Expansion of Analysis Variables
    - Learning indicators: Incorporate metrics on academic performance, failure rates, and efficiency in critical courses.
    - Student satisfaction: Incorporate surveys on perceptions of academic and administrative services to enrich the institutional vision.
    - Budgetary Impact: Link enrollment and graduation indicators to the allocation of financial resources, enabling an assessment of spending efficiency.
2. In-Depth Exploration of Predictive Analytics
    - Enrollment prediction models: Use machine learning techniques to anticipate enrollment and dropout trends.
    - Probability of Graduation: Develop algorithms that identify risk factors among students and suggest early interventions.
    - Planning Scenarios: Simulate different scenarios of enrollment growth or decline to support strategic decisions.
3. Geographic Expansion and Scalability
    - Replication in Other States: Adapt the workflow to campuses in different regions of the country, ensuring standardization of indicators.
    - Inter-institutional Comparison: Generate dashboards that allow for comparing performance across campuses, fostering best practices and collaboration.
    - National Integration: Move toward a centralized system that consolidates information from across the entire TecNM network.
4. Innovation in Visualization and Accessibility
    - Customized Dashboards: Design dashboards tailored to different user profiles (administrators, faculty, students).

- Mobile access: Optimize visualization for mobile devices, ensuring availability at all times.
- Public transparency: Publish key indicators on open portals to strengthen accountability.

5. Continuous Improvement Strategies

- Ongoing Feedback: Establish mechanisms for periodic evaluation of the BI system to adjust indicators and methodologies.
- Institutional Training: Train administrative and teaching staff in the use of analytical tools.
- Data Governance: Implement clear policies on quality, security, and ethics in information management.

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Collaborative Work Table

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Contributor in the preparation of research	Christian Marcel López Nieblas

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Writing - Review and Editing	Ramón Valenzuela Edeza, Christian Marcel López Nieblas, Parra Burgos Rito Leonel
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