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Propuesta de un modelo para analizar la calidad entre las instituciones del Tecnológico Nacional de México

Proposal of a model for the analysis of quality among institutions of the Tecnologico Nacional de México

Proposta de um modelo para analisar a qualidade entre as instituições da Tecnologia Nacional do México

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Resumen

La calidad educativa es uno de los temas que preocupa a las instituciones de educación superior y se ha tratado de medirla a través de indicadores actualizados y comparables que reflejen el estado actual de la educación a nivel internacional. El objetivo de este trabajo fue desarrollar un modelo matemático que permita analizar el desempeño de los Institutos Tecnológicos (ITs) pertenecientes al Tecnológico Nacional de México (TecNM). La originalidad del estudio se encuentra en la formulación de un modelo matemático utilizando información publicada por cada IT en los anuarios estadísticos del TecNM, de manera que no es necesario recopilar información adicional. En el estudio se usaron 21 indicadores reportados por 126 IT durante el periodo 2015-2018; se empleó un enfoque cuantitativo con un diseño longitudinal no experimental. El método para estructurar el modelo matemático incluyó el análisis factorial (AF) en etapas exploratoria y confirmatoria, combinado con regresión lineal múltiple para la formulación de las ecuaciones estructurales. Los resultados mostraron la significancia de cuatro factores con 17 indicadores en la etapa exploratoria, y cuatro factores con 9 indicadores en la etapa confirmatoria. Además, los coeficientes de los diferentes factores del modelo fueron consistentes a través del tiempo, al igual que los cinco ITs que ocuparon los primeros lugares en el índice total de desempeño calculado con el modelo. Se propone, por tanto, continuar con esta línea de investigación orientada a la generación de indicadores que sean representativos de los procesos estratégicos del TecNM y permitan la comparación con otras instituciones de educación superior.

Palabras clave: indicadores educativos, calidad educativa, análisis factorial exploratorio, análisis factorial confirmatorio, regresión lineal múltiple.

Abstract

Educational quality is one of the issues that concerns higher level institution and attempts have been made to measure it through updated and comparable indicators that reflect the current state of education on an international level. The objective of this work was to develop a mathematical model that allows the analysis of the performance of the Technological Institutes (TIs) belonging to the Tecnológico Nacional de México (TecNM). The originality of the work is found in the formulation of a mathematical model using information published by each TI in the TecNM Statistical Yearbooks, so that it is not necessary to collect additional information. In this study, 21 indicators reported annually by 126 TIs from 2015 to 2018 were used; it was used a quantitative study with a longitudinal non-experimental design. The method used to structure the mathematical model was Factor Analysis (FA) with exploratory and confirmatory stages combined with Multiple Linear Regression for the formulation of the structural equations. The results showed four significant factors with 17 indicators at the exploratory stage and the same four factor with nine indicators at the confirmatory stage. In additions, the model coefficients were consistent through the years, as well as the five TIs that appeared at the top places in the total performance index calculated with the model. It is therefore proposed to continue with this line of research aimed at generating indicators that are representative of the strategic processes of TecNM and allow comparison with other higher education institutions.

Key words: educational quality, quality indexes, exploratory factor analysis, confirmatory factor analysis, structural equations.

Resumo

A qualidade educativa é uma das questões que preocupa as instituições de ensino superior, e uma forma de a medir é através de indicadores atualizados e comparáveis que reflitam o estado atual da educação a nível internacional. Portanto, o objetivo deste trabalho foi propor um modelo matemático que permita analisar o desempenho dos Institutos Tecnológicos (TI) pertencentes ao Instituto Tecnológico Nacional do México (TecNM). A originalidade do estudo reside na formulação do modelo utilizando as informações publicadas por cada TI nos anuários estatísticos do TecNM, o que dispensa a necessidade de coleta de informações adicionais. Para isso, foram utilizados 21 indicadores reportados por 126 TIs durante o período 2015-2018 e foi utilizada uma abordagem quantitativa com desenho não experimental e longitudinal. O método de estruturação do modelo matemático incluiu análise fatorial (AF) nas etapas exploratória e confirmatória, combinada com regressão linear múltipla para formulação das equações estruturais. Os resultados mostraram a significância de quatro fatores com 17 indicadores na etapa exploratória, e quatro fatores com 9 indicadores na etapa confirmatória. Os resultados mostraram que os coeficientes dos diferentes fatores do modelo foram consistentes ao longo do tempo, assim como os cinco TIs que ocuparam os cinco primeiros lugares no índice total desenvolvido. Propõe-se, portanto, dar continuidade a uma linha de pesquisa voltada à geração de indicadores representativos dos processos estratégicos do TecNM e de outras instituições de ensino superior.

Palavras-chave: indicadores educacionais, qualidade educacional, análise fatorial exploratória, análise fatorial confirmatória, regressão linear múltipla.

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Introduction

Educational quality is one of the issues that most concerns Mexicans, since the future of the country largely depends on it. According to Duarte-Mora (2019), educational quality is a multidimensional relative concept and strongly influenced by various factors, which can be oriented towards two main branches:

a. The predictive branch, which allows diagnosing the educational institutional structure considering elements such as educational leadership, educational methods, resource management, strategy design and availability of means, among others.
b. The indicators branch, which shows the goals towards which educational quality should focus. Here, those involved in the educational process, including government authorities, directors, professors and students must assume their commitments and responsibilities.

There are international organizations that have developed a series of educational indicators with the aim of comparing and observing the improvement in educational levels between countries, such as the World Educational Indicators Program of the Organization for Economic Cooperation and Development (OECD). This organization provided many updated and comparable indicators that reflect the current state of education on an international scale (OCDE, 2017).

From the economic point of view, Nikolaevna *et al*. (2020) carried out research to establish indicators of the economic activity of educational institutions. This study required determining the income of each department, calculating its costs and cash flows, valuing the fixed assets invested in each one, as well as determining the significance coefficients of the components of the efficiency indicator. These components were evaluated by experts, who considered the specific operating conditions of the university and the objectives set by the authorities of the institutions.

The National Autonomous University of Mexico (UNAM) (2019) developed and published a catalog of activity and performance indicators. The former include demand, school population, graduations, degrees, number of research projects, research products, as well as attendance at dissemination and extension activities, among others. Regarding performance indicators, the demand/quota relationship, regularity, terminal efficiency, approval/failure rates, bibliographic production per researcher, and variations in attendance at dissemination or extension activities are mentioned, among others. These indicators are used to make decisions about project continuity, resource allocation, comparison between institutions and for standard accountability.

Some other studies have been developed and classified higher education institutions (HEIs) according to their performance using educational indicators. For example, in Colombia, the Ministry of National Education implemented a scheme where funds were allocated according to the performance of institutions, calculated through a mathematical model that generates a synthetic performance index based on the analysis of multiple factors. With this index, HEIs were classifiedand their trajectory, at a given moment, was analyzed. In addition, their evolution over time was reviewed and their strengths and weaknesses were determined (Visbal *et al*., 2020).

Dhir (2020) also developed a scale to measure the institutional effectiveness of Indian business schools using exploratory factor analysis. In this study, 15 items distributed into four large factors were used that allowed evaluating and improving the results of an institution in terms of planning, performance and effectiveness. The scale was validated in terms of its content, construct, and criterion validity, with satisfactory reliability scores on each factor.

Cornejo (2018) proposed a set of basic indicators to characterize the strategic linkage, academic, planning, resource management and quality processes. These indicators were designed to measure the educational quality in the TIs of the Tecnológico Nacional de México (TecNM) and determine the priority areas of growth for each institution.

However, although various mathematical models have been proposed to measure educational quality at the higher level, a measurement scheme for the TecNM TIs has not yet been established. For this reason, in this study, a mathematical model was developed to estimate the overall performance of TIs using information reported in the yearbooks from 2015 to 2018. The model was developed using exploratory factor analysis, confirmatory factor analysis and multiple linear regression and a global model overall index was proposed.

Materials and method

Hypothesis

It is possible to develop a mathematical model, based on structural equations, to quantify the behavior of the different performance and quality indicators using information reported in the period 2015-2018, which allows institutional comparison and decision making in the TecNM.

Materials

This research used the information reported by the 126 TIs of the National Technology of Mexico in the basic statistics yearbooks of the TecNM. Each TI annually reports the following information to TecNM: educational programs (undergraduate and graduate), total enrollment by gender, number of admission applicants and number of students accepted, absorption rate, first time admissions and readmissions, students who performed social service and professional residencies, number of students who finish their program each semester. Information on human capital is also included: number of teaching and non-teaching staff by gender, professors academic profile (degrees earned) and number of full-time professors (with or without graduate degrees).

Regarding the research process, data is reported on the number of academic bodies and their level of development, as well as professors with desirable profiles and members of the SIN (National Research System). This information was used by Cornejo (2018) to develop the TI performance indicators and create a database that served for the statistical analyzes processed in SPSS and AMOS. Table 1 shows the list of indicators and the formulas for their estimation.

Table 1. Performance indicators and formulas for their estimation

Name	Calculation formula
1. Time operation length index (A)	$\frac{\text{Years since a TI was founded}}{\text{Years of the oldest operating TI}}$
2. Student enrollment index (MT)	$\frac{\text{Total enrolled sudents in a TI}}{\text{Maximun number of students enrolled in any TI}}$
3.Educational programs index (PET)	$\frac{\text{Total educational programs in a TI}}{\text{Maximun number of educatioal programs in any TI}}$
4. Undergraduate programs index (TCL)	$\frac{\text{Undergraduate program in a TI}}{\text{Maximun number of undergraduate programs in any TI}}$
5. Accredited undergraduate programs index (CLA)	$\frac{\text{Accredited undergraduate programs in a TI}}{\text{Maximum accredited undergraduate programs in any TI}}$
6. Gradute students enrolled index (MP)	$\frac{\text{Gradute students enrolled in a TI}}{\text{Maximum gradute students enrolled in any TI}}$
7. Graduate programs index (TP)	$\frac{\text{Graduate programs in a TI}}{\text{Maximum graduate programs in any TI}}$
8. Acredited gradute programs in PNPC index (PNPC)	$\frac{\text{Acredited gradute programs in a TI}}{\text{Maximun acredited gradute programs in any TI}}$
9. Undergraduate admission applications index (SL)	$\frac{\text{Undergraduate admission applications in a TI}}{\text{Maximum undergraduate admission applications in any TI}}$
10. Absorption index (AI)	$\frac{\text{Undergraduate accepted applicants}}{\text{Total undergraduate applicants}}$
11. Graduation index (IE)	$\frac{\text{Students that complete their progams}}{\text{Students that started their programs}}$
12. Degree index (IT)	$\frac{\text{Students that obtain their Diploma}}{\text{Students that complete their progams}}$
13. Social service index (SS)	$\frac{9 * \text{Undergradute students working on SS}}{2 * \text{Undergraduate enrolled students}}$
14.Professional Residences index (RP)	$\frac{9 * \text{Undergradute students working on PR}}{2 * \text{Undergraduate enrolled students}}$

15. Professors with graduate degrees index (TDCP)	$\frac{\text{Professors with graduate degrees}}{\text{Total number of professors}}$
16. Professors with doctorate degree index (TDCD)	$\frac{\text{Professors with doctorate degree}}{\text{Total number of professors}}$
17. Full-time professors index (PTC)	$\frac{\text{Total full} - \text{time professors}}{\text{Total professors hired}}$
18. Full-time professors with graduate degrees index (PTC_CP)	$\frac{\text{Full} - \text{time professors with graduate degrees}}{\text{Total number of professors}}$
19. Academic bodies index (AC)	$\frac{\text{Total academic bodies in a TI}}{\text{Maximun academic bodies in any TI}}$
20. Professors with desirable profile index (TPPD)	$\frac{\text{Professors with desirable profile}}{\text{Full} - \text{time professors with graduate degrees}}$
21. Professors in the SNI index (SNI)	$\frac{\text{Professors in the SNI in a TI}}{\text{Maximun number of professors in the SNI in any TI}}$

Source: Cornejo (2018)

Method

In this work, a quantitative study with a longitudinal non-experimental design was developed. Using the information reported in the yearbooks during the period 2015-2018, the indicators shown in Table 1 were calculated for each TI at each year. Then, an exploratory statistical analysis was carried out using principal components analysis to estimate the significant factors and their association with the indices mentioned in Table 1 (base model). Subsequently, a confirmatory factor analysis (CFA) was used to validate the base model and verify the consistency of the latent variables (factors) with the data from the other years (Brown, 2015). Furthermore, it was ensured that the models obtained met the fit criteria included in tables 2 and 3 (Hu and Bentler, 1999).

Using the developed model, the loadings of each factor for each TI were determined using the AMOS and SPSS 24 *software* for the analysis of the data generated. The sum of the loads of each TI represented the total index, which was normalized using the highest of the indices obtained for all the TIs. With the normalized total indices, the TIs were arranged in descending order and the position of each TI in the period considered was analyzed.

Finally, to develop a predictive model of the total index for any TI, a multiple linear regression process was carried out using the factor loadings of all the technologies analyzed.

Table 2. Goodness of fit tests for confirmatory factor analysis.

Parameter	Limiting values
χ^2 Chi square/Degrees of freedom CMIN/DF (Byrne, 2016).	<3 good < 5 sometimes allowed
CFI Comparative Fit Index	> 0.95 excellent > 0.90 traditional > 0.80 sometimes allowed
SRMR Standardized square root of the mean square of the residuals	< 0.09
RMSEA Square root of approximation error	< 0.05 good Between 0.05 and 0.10 moderate > 0.10 poor fit
Pclose P value for the model	> 0.05

Sources: Hu and Bentler (1999), Hair *et al*. (2014) and Byrne (2016)

Table 3. Criteria for the reliability and validity of the model

Parameter	Limiting values
Average Variance Extracted (AVE)	AVE > 0.5
Construct validity (CR)	CR > 0.7
Maximum Shared Variance (MSV)	MSV < AVE

Source: Hair *et al*. (2014) and Gaskin (2016a)

Results

The exploratory factor analysis was carried out with SPSS 24 *software*, using the principal components extraction method and selecting as significant factors those with eigenvalues greater than 1. Table 4 shows the eigenvalues, the sums of loading extraction and the sum of loading rotation for the four significant principal components for the data from 2015. The largest eigenvalue (8.117) corresponds to the most significant factor, which can explain up to 47.749% of the total variance. When considering the four factors with eigenvalues greater than unity, the accumulated variance reached 78.415%. Furthermore, axis rotation strengthened the association of the indicators with the corresponding main factors.

Table 5 shows the communality matrix of the indicators extracted in each year using the Varimax rotation method and Kaiser normalization. Indicators that presented communalities less than 0.5 were eliminated in the subsequent stages of the analysis due to their low correlation with any of the four main components (factors).

Table 6 distributes the 17 indicators into the four significant factors identified in the exploratory stage. We named the factors as follows: Researchers, Institution, Professors and Students. The indicators associated with the factor Researcher include the following: SNI, TP, MP, AC, TDCD and AI. The factor Institution was associated with the following indicators: TCL, PET, MT, SL and A. The factor Professors was associated with the following indicators: PTC_CP, TDCP and PTC. Finally, the factor Students was associated with the indicators SS, IE and RP.

When repeating the principal components extraction procedure with data from other years, it was observed that four principal components were significant and that the association of indicators and factors was similar. At the conclusion of the exploratory factor analysis, it was determined that for any year there were four significant main components, and that the number of indicators was reduced from 21 to 17 with the elimination of the indicators CLA, PNPC, IT and TPPD due to its loadings turned out to be less than 0.5.

Table 4. Total variance explained by principal component without and with rotation (data from 2015)

Main component	Load extraction sums			Charge rotation sums		
	Own value	% variance	% accumulated	Own value	% variance	% accumulated
1	8.117	47.749	47.749	4.490	26.413	26.413
2	2.403	14.135	61.884	3.664	21.551	47.964
3	1.755	10.322	72.206	2.765	16.256	64.229
4	1.056	6.209	78.415	2.412	14.187	78.415

Source: Villalobos (2020)

Table 5. Matrix of extraction communalities with Varimax rotation for each indicator by year

Indicators	2015	2016	2017	2018
Time operation length index (A)	0.783	0.860	0.723	0.739
Student enrollment index (MT)	0.797	0.841	0.843	0.817
Educational programs index (PET)	0.903	0.888	0.894	0.905
Undergraduate programs index (TCL)	0.829	0.796	0.809	0.724
Gradute students enrolled index (MP)	0.825	0.825	0.850	0.812
Graduate programs index (TP)	0.897	0.897	0.900	0.873
Undergraduate admission applications index (SL)	0.826	0.833	0.795	0.827
Absorption index (AI)	0.642	0.649	0.614	0.727
Graduation index (IE)	0.721	0.648	0.552	0.718
Social service index (SS)	0.727	0.556	0.702	0.690
Professional Residences index (RP)	0.640	0.787	0.739	0.659
Professors with graduate degrees index (TDCP)	0.718	0.760	0.673	0.717
Professors with doctorate degree index (TDCD)	0.658	0.777	0.742	0.717
Full-time professors index (PTC)	0.780	0.819	0.779	0.695
Full-time professors with graduate degrees index (PTC_CP)	0.904	0.927	0.939	0.879
Academic bodies index (AC)	0.825	0.830	0.756	0.796
Professors in the SNI index (SNI)	0.854	0.904	0.867	0.765

Source: Cornejo (2018) and Villalobos (2020)

Table 6. Association of indicators by principal component using 2015 data with Varimax rotation and Kaiser normalization

Indicator	Main components			
	Researchers	Institution	Professors	Students
SNI	0.854			
TP	0.836			
MP	0.816			
AC	0.784			
TDCD	0.589			
AI	-0.564			
TCL		0.905		
PET		0.824		
MT		0.729		
SL		0.693		
A		0.596		
PTC_CP			0.901	
TDCP			0.825	
PTC			0.702	
SS				0.831
IE				0.783
RP				0.781

Source: Villalobos (2020)

In the second stage, a confirmatory factor analysis was carried out using the base model with 4 factors and it was validated with the AMOS 22 *software* and the Model Fit Measures plugin by Gaskin (2016a). In this analysis, it was found that out of the 17 initial indicators, only 9 were associated with the four factors and met the established standards (Gaskin, 2016c).

Figure 1 shows a graphical representation of the model in the confirmatory stage. The values of the covariances between the factor variables and between the factors were included. The indicators associated with each factor were as follows: factor Researchers (SNI and AC); factor Institution (PET, MT and AI); factor Professors (PTC_CP and PTC); and factor Students (RP and SS).

Table 7 presents the goodness-of-fit indices for the four years analyzed. The results indicate that the model meets the criteria of Hu and Bentler (1999) except for the RMSEA value in 2017. The plugin suggested the eliminaton of the PTC indicator so that the RMSEA value approached the validation criterio. However, it was decided to keep the indicator in the model, since it was considered that other authors such as Gaskin (2016b) mentioned more flexible criteria for the acceptance of the models. In this study, the model met the criterion for the other analyzed three years. Furthermore, removing the PTC indicator would leave the factor with only one indicator, which is not suitable for representation of the overall model.

Table 8 shows the results of the reliability and validity evaluation for each model. According to the criteria presented in Table 3, it was concluded that the models presented good results, although there is convergent validity because CR for institution es less than de AVE (Gaskin. 2016c).

Table 7. Results of the goodness-of-fit tests in the validation of the confirmatory factor analysis model.

Index	2015	2016	2017	2018
CMIN/DF	1.805	1.286	2.060	1.479
CFI	0.960	0.984	0.940	0.973
SRMR	0.056	0.059	0.085	0.075
RMSEA	0.097	0.059	0.114	0.077
Pclose	0.068	0.373	0.018	0.211

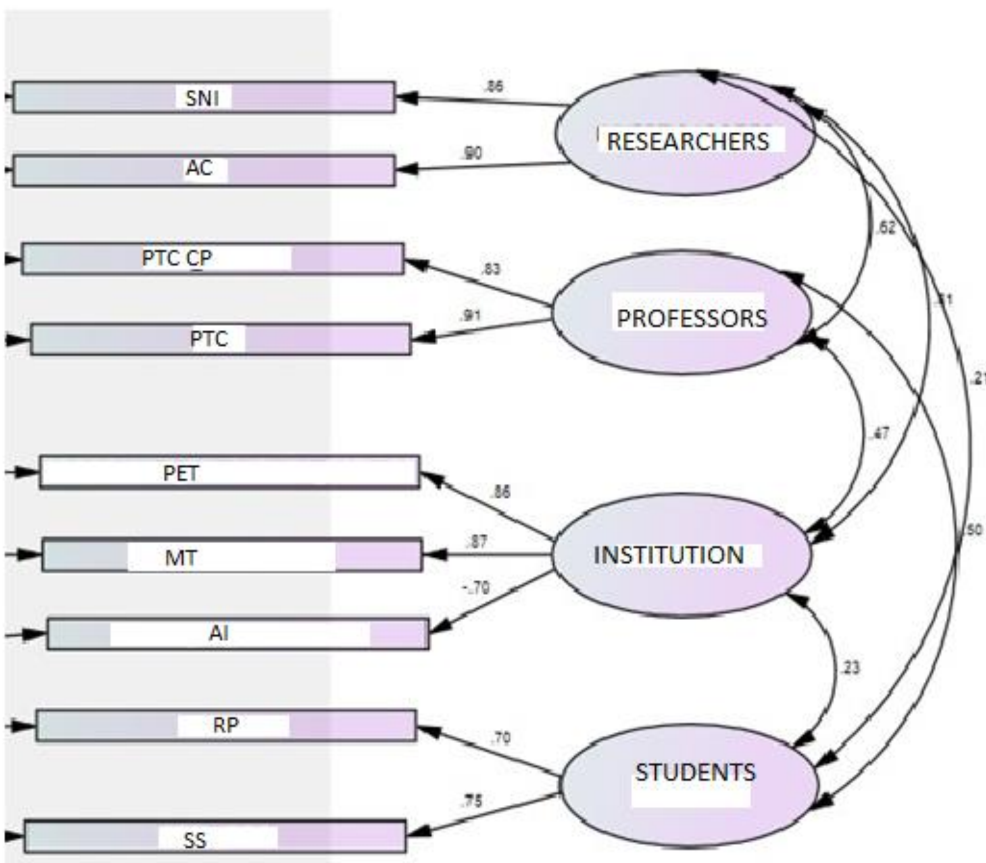
Source: Gaskin (2016c), Model Fit Measures, AMOS plugin

Table 8. Validity and reliability of the confirmatory factor analysis models.

Year	Parameter	Factors			
		Institution	Researchers	Professors	Students
2015	CR	0.521	0.876	0.872	0.703
	AVE	0.676	0.780	0.773	0.545
	MSV	0.676	0.676	0.338	0.228
2016	CR	0.512	0.875	0.861	0.689
	AVE	0.664	0.778	0.756	0.526
	MSV	0.664	0.664	0.384	0.248
2017	CR	0.577	0.860	0.887	4,181
	AVE	0.642	0.754	0.797	6,102
	MSV	0.676	0.676	0.318	0.003
2018	CR	0.593	0.838	0.885	0.725
	AVE	0.644	0.722	0.795	0.587
	MSV	0.750	0.750	0.325	0.082

Source: Stat tools by Gaskin (2016b)

Figure 1. Model obtained for 2015 after confirmatory factor analysis.



Source: Villalobos (2020)

With the model obtained for each year, the factor loadings were calculated for each TI using the AMOS 22 *software*. Table 9 presents partial results for the top eight TIs with information of the year 2015. Each TI total index was normalized using the largest value among all TI for every year. The values of the maximum total indices for the years 2015-2018 were 215.05, 208.66, 237.01 and 217.42 respectively.

For the 2015 data, only 6 TIs obtained an index greater than or equal to 0.7, while 21 presented an index less than 0.3. This information is detailed in Table 10, which shows the percentage contributions of each factor in the model for each TI with data from 2015. Then, with these values, the average contribution of each factor in the model was calculated.

Table 9. Factor loadings for each TI for the year 2015 (partial data)

Technological Institute	Students	Institution	Faculty	Researchers	Total index	Normalized index
Celaya	3.16	53.73	72.81	85.35	215.05	1.00
Tijuana	2.78	70.99	47.81	62.9	184.48	0.86
Morelia	3.3	50.58	68.84	58.69	181.41	0.84
Madero City	4.18	53.87	51.87	50.53	160.45	0.74
Orizaba	3.88	38.59	69.66	47.4	159.53	0.74
Durango	3.57	51.93	58.88	43.83	158.21	0.74
Aguascalientes	2.66	43.11	55.99	46.3	148.06	0.69
Veracruz	3.79	32.8	65.18	42.62	144.39	0.67

Source: Villalobos (2020)

Table 10. Percentage participation of each factor in each TI for the year 2015 (partial data)

Technological Institute	Students	Institution	Faculty	Researchers
Celaya	1.47	24.98	33.86	39.69
Tijuana	1.51	38.48	25.92	34.10
Morelia	1.82	27.88	37.95	32.35
Madero City	2.61	33.57	32.33	31.49
Orizaba	2.43	24.19	43.67	29.71
Durango	2.26	32.82	37.22	27.70
Aguascalientes	1.80	29.12	37.82	31.27
Veracruz	2.62	22.72	45.14	29.52

Source: Villalobos (2020)

To obtain the linear multiple regression model, loadings of each factor for each TI were used. Table 11 shows the structural prediction equations of the multiple linear regressions for each factor, as well as the normalized global performance index equation. The coefficients of the equations for each year are presented in table 12, while the percentages of contribution of each factor per year are shown in table 13. It was observed that the factor Professors had the greatest overall impact with a decreasing trend along the time. This trend could be explained by the new regulations for hiring new full-time professors who had earned graduate degrees. Therefore, it is expected that the differences between Professors in all TI will continue decreasing.

The factor Institution presented an increasing trend during the analyzed period because consolidated TI had more chances of increasing the number of new programs as well as their enrollment.

The factor Researchers showed a low participation in 2015 and was strengthened during the following years due to the boost that research had had and the various financing programs granted by TecNM, Conacyt and Prodep, among others.

Table 11. Regression equations proposed to calculate each factor and the model index

$\mathrm{PROFESSORS} = \mathrm{K1} + \mathrm{K2} * \mathrm{PTC} + \mathrm{K3} * \mathrm{PTC\_CP}$
$\mathrm{STUDENTS} = \mathrm{M1} + \mathrm{M2} * \mathrm{RP} + \mathrm{M3} * \mathrm{SS}$
$\mathrm{INSTITUTION} = \mathrm{N1} + \mathrm{N2} * \mathrm{PET} + \mathrm{N3} * \mathrm{MT} + \mathrm{N4} * \mathrm{AI}$
$\mathrm{RESEARCHERS} = \mathrm{P1} + \mathrm{P2} * \mathrm{AC} + \mathrm{P3} * \mathrm{SIN}$
GLOBAL MODEL OVERALL INDEX (GMOI)
$\mathrm{GMOI} = \frac{\mathrm{PROFESSORS} + \mathrm{STUDENTS} + \mathrm{INSTITUTION} + \mathrm{RESEARCHERS}}{\mathrm{MAXIMUM\ TOTAL\ INDEX}}$

Source: Cornejo (2018) and Villalobos (2020)

Table 12. Summary of coefficients for the regression equations for each year

Indicator coefficients	2015	2016	2017	2018
Professors				
K1	0.587	0.232	-0.551	0.111
K2	0.477	0.398	0.549	0.106
K3	0.585	0.703	0.493	0.968
Students				
M1	0.376	0.026	-0.171	0.064
M2	0.020	0.055	0.032	0.004
M3	0.024	0.012	0.022	0.046
Institution				
N1	2,676	0.95	-1,227	-1,666
N2	0.439	0.445	0.662	0.813
N3	0.357	0.328	0.259	0.19
N4	-0.153	-0.167	-0.091	-0.064
Researchers				
P1	5,742	7,230	11,372	11,845
P2	0.505	0.545	0.455	0.447
P3	0.359	0.346	0.454	0.451

Source: Cornejo (2018) and Villalobos (2020)

Table 13. Percentages of participation of each factor in the model by year

Factor	2015	2016	2017	2018
Researchers	19	25	26	26
Professors	56	46	43	38
Institution	21	22	28	32
Students	4	5	3	4

Source: Cornejo (2018) and Villalobos (2020)

With the normalized total indices, a list with the position of each TI was developed. The first position was occupied by the TI with the total normalized index equal to unity. Table 14 shows a partial list with the positions of the top five TI in the analyzed period.

Table 14. Representative table of the technological companies with the highest values in their institutional index by year

Position	2015	2016	2017	2018
1	Celaya	Celaya	Celaya	Celaya
2	Tijuana	Tijuana	Tijuana	Tijuana
3	Morelia	Morelia	Morelia	Morelia
4	Madero	Durango	Durango	Madero
5	Orizaba	Madero	Madero	La Laguna

Source: Cornejo (2018) and Villalobos (2020)

Discussion

Regarding the goodness of fit indices, it was observed that for 2016 the validity criteria of Hu and Bentler (1999) presented in table 2 were perfectly met. In the periods 2015 and 2018, the models largely met the validity criteria. The values of the goodness of fit indices were found within the tolerance limits established by Hu and Bentler (1999). However, in 2017 the results show that the model met the validity criteria of Hu and Bentler (1999), as indicated in table 2 (Cutoff Criteria), except for the RMSEA, whose value was 0.11, which is higher than the established upper limit of 0.10. Despite of, the model was preserved because other opinions—such as that of Hooper *et al.* (2010)—recommend limit values for the RMSEA in the range of 0.05 to 0.10.

Regarding the validity and reliability for each year's model, it was observed that the models met the criteria established in Table 3 of this work.

For each year, a model was built with structural equations and the effect of each factor was calculated globally as well as by each TI. Overall, it was found that the participation of each factor for each year behaves as follows: the most impactful factor was Professors, closely followed by that of Institution and Researchers, finally, with very low contribution the factor Students. These results were consistent for all the TI.

The TIs that have consolidated graduate programs normally carry out research and their members participate in different activities that contribute to the Pofessors and Researchers factors. With respect to the factor Students, its overall contribution to the model was small because the current indices correspond to actions that have been developed for many years at all TIs. The differences in the indicators of this factor between all TI are small. However, the model can distinguish those small differences betweeen TIs.

It is important to note that this type of models provides a starting point for other research based on the analysis of educational indicators. In other words, the analysis itself does not improve educational quality, but it serves as a source of information to compare the performance of all TIs and it may allow to take control actions that improve the overall performance of the TIs.

Finally, in this study, it was not possible to compare the results of this work with published results of other higher education institutons due to the diferences in the definitions of the performance indices used.

Conclusions

In this work, 21 performance indices published in the 2015-2018 yearbooks of technological institutes were analyzed. Exploratory and confirmatory factor analysis strategies were used to determine the statistically significant factors with the greatest impact. The following four factors were identified: Researchers, Professors, Institution and Students.

Out of the 21 originally indicators reported in the yearbooks, only 9 were necessary to integrate the four final model factors. Likewise, structural equations were developed through multiple linear regression for each factor and a total index was quantified for each TI.

The developed model generated useful information for each TI and a detailed review of each indicator may help TI'directors to modify institutional activities that improve the overall institutional performance. Besides, in accordance with the TecNM development plans, new indicators should be included in future yearbooks that allow strengthening the institutional development prediction models. For example, activities related to relationships with other educational institutions and companies, the participation of students in technological development and research projects, the inclusion of students in scientific and divulgation publications, the mobility and exchange of students between institutions, as well as participation in dual education programs, conferences, competitions, etc.

If a set of new data is provided by TIs, the actual model can be improved by including new indices. In this sense, it is crucial that these indicators are disseminated among TecNM institutions to promote improvements both at the institutional and general levels. Furthermore, the use of new technologies and database management will allow information and models to be systematized to guarantee accurate and immediately updated data for timely decision-making on the path to institutional improvement.

On the other hand, regarding the limitations found, the type of information available to the public in the TecNM can be mentioned. The yearbooks of the planning department were not published in a timely manner, the yearbooks for the years 2019, 2020 and 2021 recently appeared, which is why the analysis of these years was not included in this research.

Furthermore, the information available is not optimal to generate indicators that fully represent each strategic process of the TecNM. Therefore, other types of data are required that strengthen information related to student performance, the development of research projects, inter-institutional and industrial links, and administrative processes.

Future lines of research

The models presented in this work are dynamic and can be enriched with the information provided to the TecNM Planning Office. In this sense, it is worth highlighting that this research has demonstrated the usefulness of using the information reported in yearbooks, which should promote the continuous updating of these documents. In this way, interested parties will be able to have a complete information bank and will be able to follow a line of research aimed to generate new indicators that adequately represent the behavior of the different strategic processes of TecNM and other higher education institutions.

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