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Measuring Critical Success Factors for Six Sigma in Higher Education Institutions: Development and Validation of a Surveying Instrument

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ABSTRACT Critical success factors are key elements that enable the success of projects. This research work proposes the design and validation of an instrument to evaluate the implementation of six sigma critical success factors during improvement projects in higher education institutions. Eleven critical success factors were selected from the literature on the six sigma methodology, including managerial participation and commitment, six sigma linkage with the institutional strategy, six sigma linkage with suppliers, communication, and team member selection, among others. The instrument was validated among Mexican higher education institutions, from which 743 surveys were collected. Namely, the instrument was administered to experienced improvement project developers. Then, the collected data were analyzed, first by means of an exploratory factor analysis, and later with a confirmatory factor analysis using software program SPSS Amos®. Our results demonstrate that the proposed instrument is statistically valid, so it can be used by higher education institutions to evaluate how Six Sigma critical success factors are handled during improvement projects development. Similarly, the survey can help universities detect areas of opportunity when adopting the six sigma methodology and fit models to evaluate how critical success factors interact among them to achieve the expected results of improvement projects.

INDEX TERMS Confirmatory factor analysis, construct validation, higher education, improvement projects, six sigma.

I. INTRODUCTION

To ensure the quality of their academic and administrative processes, Higher Education Institutions (HEIs) from around the world adopt quality methodologies to guide their improvement projects (IPs) [1]. Quality management is a strategy that provides tools and techniques for the successful application of quality principles in diverse environments [2], [3]. Likewise, [4] mention that public and private HEIs have progressively introduced quality management systems in the last two decades. This practice is common in the United States, the United Kingdom and countries in Europe, as well as in the Middle and Near East, including countries in Africa, southwest Asia and mainly China, as well as Australia and New Zealand [5]–[7]. Also, [8] mention that there are many documented studies on the application of quality management systems in the field of higher education such as Total Quality Management (TQM), Six Sigma (SS), Knowledge Management, Lean Thought, Social Corporate Responsibilities and ISO 9000. In addition to these methodologies, the education sector has opted for quality models such as the European Foundation for Quality Management (EFQM) excellence model, the Malcolm Baldrige National Quality Award (MBNQA), the Singapore model Quality Award (SQA) and School Excellence Model [4]. For instance, according to [9], HEIs work with management systems, such as external accreditation and certification bodies (e.g. ISO 9001), to improve their processes and face global

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competition. Thus, generally, but perhaps mainly due to the limited availability of resources in developing countries such as Mexico, it is important to analyze how HEIs implement IPs in order to determine those elements that increase the likelihood of obtaining successful results, thereby directing institutional efforts toward these elements.

This study designs and validates an instrument that seeks to measure the critical success factors (CSFs) that intervene in the development of IPs in HEIs, which were identified in the worldwide SS literature on service industries and the data collected from Mexican public universities. Thus, although the scope of this study is aimed at all public HEIs interested in adopting SS as a framework for developing IPs, this instrument is more likely to be suitable for application in those countries that have similar socioeconomic conditions to Mexico.

In the literature, there is a lack of evidence of how HEIs are performing quality IPs. Such evidence can provide valuable information for improving the competitiveness of HEIs in today's globalized world. This study seeks to address this research gap. It is important to mention that surveys are instruments that require a series of properties that ensure their reliability and validity [10], so it is essential to have a validated and reliable survey that ensures that the designed questionnaire and the determined items are adequate to measure what is intended to be measured [11]. Therefore, this study describes the steps involved in designing and validating an instrument that reliably measures the degree of implementation of SS CSFs in the higher education sector. This manuscript was written with the following sections: section I presents the introduction; section II provides a literature review; section III describes the objective of the investigation; section IV presents the methodology and results of the study; section V provides the discussion; section VI details the limitations and recommendations for future lines of research, and section VII provides the conclusions.

II. LITERATURE REVIEW

A. CRITICAL SUCCESS FACTORS (CSFs)

According to [12], [13], CSFs were popularized by Rockart [14]. Namely, CSFs are a series of factors that are essential to an organization, without which any improvement initiative has a low probability of success. The concept systematically highlights the key areas that management should carefully consider to realize its performance goals. By understanding the CSFs for the implementation of a system, an organization can successfully determine the difficulties that critically affect the process, thereby eliminating or avoiding any problems that may contribute to its failure [15]. Currently, the benefits of CSFs are more noticeable in the manufacturing industry thanks to the implementation of strategies such as Total Quality Management (TQM), ISO 9001, Six Sigma (SS), Kaizen, lean thinking, and the 5Ss, to name but a few. Fortunately, these quality improvement strategies, along with their concepts, are now being tested in the service sector, including education. For instance, some HEIs that offer engineering programs rely on these strategies as a frame of reference for conducting IPs [8].

The study of CSFs through an instrument has been carried out in other sectors, such as electronic manufacturing service, where [16] conducted a pilot study to identify the main CSFs for the implementation of Lean Six Sigma (LSS), and based on these factors, they built a questionnaire. Another similar study is one conducted by [17] in small and medium manufacturing companies, and an instrument was designed to capture the point of view of the respondent on CSFs and the barriers faced in the implementation of SS. On the other hand, [18] present an LSS study focusing on the CSFs identified in the literature through a survey for both manufacturing and service companies. Currently, no instrument exists with the objective of capturing SS CSFs in the higher education sector.

B. SIX SIGMA (SS)

The SS methodology was developed at Motorola in 1987 by engineer Bill Smith. The original SS program relied on several of the systematic and rigorous tools associated with today's SS programs [19]. To Reoseker and Pohekar [20], SS is an improvement strategy that reduces variation in any process in order to eliminate defects or faults. One of the fundamental components of this strategy is the DMAIC methodology (define, measure, analyze, improve, and control), which draws upon a set of tools and techniques in a logical sequence to conduct projects and achieve sustainable benefits [21].

Since quality has become an essential concept of education, it is argued that Motorola's methodology might be necessary for universities that are willing to continuously improve and thus reach educational excellence [22], [23]. This methodology encourages decision-making to be based on the analysis of data and not only on intuitions or forebodings [24], something that frequently happens in HEIs. The term SS begins to sound strong in the educational environment, especially because of the growing importance of what they call "quality in education". Particularly in higher education, where the final products of the system can have a direct impact on the quality of the organizations that hire them. SS is considered a viable strategy since it is a specific, measurable and well-defined methodology. It should be appreciated the usefulness, applicability and integration of SS tools and techniques to address real-world problems [1], [13], [22], [23], [25]–[28]. In this sense, IPs are the fundamental part of the SS methodology [29], and when properly managed, they result in significant benefits. Unfortunately, there is a shortage of literature regarding HEIs that conduct quality IPs, which represents an opportunity for the scientific community to develop and validate an instrument that identifies how CSFs for SS are handled among these HEIs when developing IPs.

III. RESEARCH GOAL

The instrument to be developed and validated in this work will allow us to collect necessary data on the implementation of SS CSFs among HEIs during IPs. Therefore, the ultimate goal of this research is to propose a tool that can be employed by decision makers of HEIs when they feel interested in continuously improving institutional processes through IPs, thereby relying on the SS framework for their implementation.

IV. METHOD

This study used a cross-sectional survey design to collect data on the implementation of SS CSFs among HEIs during IPs. The methodology adopted to develop and validate our survey instrument is based on generally accepted principles in the development and validation of instruments to measure variables in the social sciences using the psychometric method [30]–[32]. This method has been used as a reference by researchers to develop and validate questionnaires [11], [33], [34]. The process for the design and validation of the questionnaire used in this investigation is also based on the above criteria and comprises the following three stages, thoroughly discussed below: instrument design, construct definition and indicator definition. Administering the instrument includes data collection, and finally, the statistical analysis involves the verification of assumptions, the analysis of the data through factor analysis and the validation of the construct.

A. INSTRUMENT DESIGN

An important part of the instrument design process is identifying the constructs to be studied. To design the survey, we performed a literature review on CSFs for SS implementation in educational settings and the service sector. The literature review was carried out in the EBSCO, ELSEVIER, EMERALD, IEEE, SCOPUS and SPRINGER databases. The inclusion criteria were publications from the year 2000 to present and publications that address CSFs in the areas of education and the service industry. Search keywords such as six sigma AND education, six sigma AND higher education, six sigma AND service and six sigma AND critical success factors were used. Finally, 66 articles were identified for review, and with this information the frequencies of the CSFs most mentioned in the literature were obtained, resulting in a total of 25 CSFs.

In the reviewed articles, the factors that make up slightly more than 82% of the mentions were selected as the basis for the design of the data collection instrument. Table 1 lists these CSFs with their respective conceptual definitions and references. The factors yielded by the analysis that are the objects of study are as follows: Top Management Involvement and Commitment (TM), Training and Education (TE), Select Team Members and Teamworks (TW), Link SS with Institutional Strategy (LI), Cultural Change (CC), Link SS with Human Resources (HR), Clear Performance Metrics (CM), Link SS with Costumers (LC), Communication (C), Link SS with Suppliers (LS) and Benefits (B).

TABLE 1. Conceptual definition of constructs.

Construct	Description
Cultural Change (CC)	Adjust to an organizational culture through sustained communication, motivation, and high-quality education [35], [36].
Top Management Involvement and Commitment (TM)	Must show leadership and commitment. Without top management support, projects are a waste of time and energy [13], [37], [38].
Training and Education (TE)	Provides a clear sense of purpose to human resources and allows them to understand the principles, tools, and techniques of the improvement strategy [35], [39], [40].
Link SS with Costumers (LC)	The challenge is to understand the voice of all the customers and develop effective strategies to satisfy their needs [13], [35], [41].
Link SS with Institutional Strategy (LI)	Implies associating IPs with the institution's strategy and priorities. Similarly, IPs must aim at the continuous improvement of processes and must directly impact customers and financial and operating benefits [13], [42]–[44].
Communication (C)	Effective communication allows organizations to develop a common language for change and improvement [13], [37].
Select Team Members and Teamworks (TW)	Team members are selected according to their technical, analytical, interpersonal, knowledge transfer, and teamwork skills [43], [45].
Clear Performance Metrics (CM)	Clear goals increase the scope of the improvements, employee efforts, and employee commitment toward quality [46], [47].
Link SS with Human Resources (HR)	The results and achievements of IPs are key indicators of human resources performance and compensations. They also indicate to what extent the goals of the improvement strategies are incorporated into the individual goals of the employees [16], [37].
Link SS with Suppliers (LS)	Evaluating suppliers with respect to quality and providing training and technical assistance ensure quality resources and services [38]
Benefits (B)	A benefit is associated with a positive action or result that favors people and organizations, the benefit of implementing the SS methodology is related to quality and productivity.

In this study, the 11 CSFs represent the latent variables to be studied through the survey. However, note that latent variables cannot be measured directly and must be

TABLE 2. Operationalization of top management involvement and commitment.

Construct	Indicators	Variables	Items
TM	Strategy handling	TM1	Top management's support and active participation in Six Sigma improvement activities (training, project selection, stage review, and result evaluation) [51].
		TM2	Top management creates an environment of empowerment, learning, and innovation [51].
		TM3	Top management assumes responsibilities for SS performance [16].
	Active participation	TM4	Top management is involved during the selection of team members and team leaders according to current business /customer requirements. Similarly, top managers understand how their involvement can impact on the success of SS projects [52].
	Quality culture implementation	TM5	Leadership encourages employee participation in SS implementation [53].
	Availability of financial resources	TM6	Top management allocates the appropriate budget and the necessary resources for SS projects [53].

operationalized [48], [49]. Consequently, the final survey should be the product of such an operationalization, performed at the observational level by defining a set of indicators that would lower the level of abstraction of each latent variable and will allow us to observe it in reality [50]. Therefore, according to the conceptual definitions introduced in Table 1, a series of indicators were defined for each construct. For instance, Table 2 presents the construct named Top Management Involvement and Commitment, defined by four indicators: strategy handling, active participation, quality culture implementation and availability of financial resources. Similarly, we provide the survey item that corresponds to each indicator and the references as follows: for strategy handling, items TM1, TM2 and TM3 correspond; active item corresponds to item TM4; quality culture implementation has item TM5; and finally, availability of financial resources corresponds to item TM6.

The Likert-type rating scale is a popular option to measure latent variables through a set of related items [54], [55]. In Likert scales, each participant must individually respond to a series of statements by selecting the scale value or option that best represents his/her opinion. In this study, we propose a five-point Likert scale to measure the implementation of CSFs for SS in HEIs as follows: never (1), almost never (2), sometimes (3), usually (4), and always (5). Similarly, the survey was structured in five sections. The first three respectively aimed at introducing the instrument, collecting general information on the surveyed HEIs, and analyzing the quality tools usually implemented by these universities when developing IPs. Then, the goal of the fourth section was to assess the use of the CSFs for SS during the implementation of such IPs. Finally, the fifth section sought to analyze the benefits that the HEIs obtain from the IPs implemented.

B. INSTRUMENT ADMINISTRATION

This research was conducted among Mexican public HEIs in order to reach a higher impact on Mexico's educational context. In fact, according to Mexico's Public Secretariat of Education [56], public universities represent over 70% of the national enrollments in higher education. The instrument aimed at quality coordinators and experienced IP developers. In the end, 743 surveys were collected using an online platform from 400 different academic units across 318 public HEIs. The State of Mexico reported the highest participation rate; namely 14% of the total surveys, and it was then followed by Sonora and Hidalgo, with 8% and 6%, respectively. As for the job positions, 32% of the collected surveys were answered by heads or quality coordinators, while approximately 20% were answered by professors who are also experienced IP developers.

C. STATISTICAL ANALYSIS FOR INSTRUMENT VALIDATION

Psychometric theory refers to latent variables and their evaluation. Factor analysis is a statistical methodology that addresses indirectly observable variables such as constructs [30] and is used to assess the reliability and validity of the construct [11], [30], [32], [33]. According to [54], [57], [58] there are four important issues to consider in any survey validation process: missing data, outliers, univariate and multivariate normality assumptions, and multicollinearity. Missing data occur when respondents do not rate a given item. In this study, the program used to administer the survey online was conditioned so that no incomplete surveys could be submitted, thereby addressing the issue of missing data. On the other hand, outliers are observations with a unique combination of identifiable characteristics that are clearly different from the other observations [54]. When analyses comprise more than two variables, it is important to objectively measure the multidimensional positions of each observation in relation to some common point. This is handled through Mahalanobis distance. In this sense, Kline [57] recommends a conservative level of statistical significance where $p < 0.001$. According to our calculations, the database reported 186 surveys as outliers, which were all removed from the analysis after a thorough examination. Therefore, the following validation calculations were performed with the remaining 557 surveys. To improve the normality of the database, the surveys were eliminated since, as mentioned by [59], [60], this assumption must be fulfilled to use the maximum likelihood method for the factor extraction, which as mentioned later was used in the present investigation.

To measure data normality in variables, DeCarlo [61] suggests relying on skewness and kurtosis. In this sense, the

TABLE 3. Results from the construct validity tests.

Construct	Variable	Kurtosis	VIF	Factor Loading	Eigenvalues	Cronbach's alpha
CC	CC1	2.118	2.993	0.854	2.001	0.856
	CC2	0.852	2.968	0.866		
	CC3	2.812	2.061	0.733		
TM	TM1	5.697	3.695	0.851	4.016	0.940
	TM2	1.590	4.570	0.890		
	TM3	5.018	4.612	0.888		
	TM4	0.218	3.860	0.858		
	TM5	3.468	4.244	0.883		
	TM6	0.544	2.562	0.756		
TE	TE3	-2.013	2.632	0.772	2.066	0.883
	TE5	-2.644	3.621	0.864		
	TE6	0.700	4.246	0.922		
C	C1	0.685	3.940	0.861	3.387	0.927
	C2	-1.255	2.450	0.738		
	C3	-0.295	4.957	0.891		
	C4	-0.894	5.598	0.920		
	C5	-1.041	3.966	0.849		
LC	LC3	-2.336	2.601	0.733	2.231	0.897
	LC4	-0.057	3.801	0.871		
	LC5	0.093	3.724	0.857		
	LC6	2.144	3.727	0.858		
LI	LI1	-0.053	2.977	0.782	2.502	0.929
	LI2	1.851	5.233	0.891		
	LI3	1.325	3.720	0.841		
	LI4	2.476	5.307	0.903		
	LI5	0.412	3.978	0.845		
TW	TW1	-5.098	2.412	0.744	1.334	0.847
	TW2	-3.046	3.178	0.883		
	TW4	-2.955	2.76	0.806		
CM	CM1	4.770	5.296	0.890	2.800	0.953
	CM2	1.715	4.822	0.881		
	CM3	1.938	5.536	0.904		
	CM4	2.355	5.864	0.914		
	CM5	3.756	5.193	0.891		
HR	HR4	-2.869	3.147	0.818	1.862	0.903
	HR5	-1.680	3.921	0.882		
	HR6	-1.076	4.844	0.919		
LS	LS1	0.425	3.916	0.844	4.207	0.935
	LS2	0.076	3.975	0.850		
	LS3	-1.911	4.229	0.874		
	LS4	-3.858	4.089	0.824		
	LS5	-2.166	3.434	0.800		
	LS6	-1.609	3.868	0.851		
B	B2	1.316	3.982	0.800	6.946	0.959
	B3	0.312	4.370	0.829		
	B4	2.172	2.937	0.796		
	B5	4.994	3.929	0.834		
	B6	2.468	4.707	0.870		
	B7	1.772	5.673	0.902		
	B8	0.618	4.778	0.893		
	B9	0.169	4.460	0.857		
	B10	2.532	5.371	0.891		
	B11	0.580	2.379	0.716		

author claims that the value of the standardized kurtosis index in a normal distribution should be equal to 3. Similarly, Kline [57] considers as a conservative general rule that absolute values of the kurtosis index greater than 10 may suggest a problem, and values higher than 20 may indicate a more serious one. In this study, the kurtosis index was calculated for each study variable. As shown in Table 3, the index values obtained are lower than those previously warned. Namely, nine variables report absolute kurtosis values greater than 3, yet none of the variables shows a value higher than 10. Such results demonstrate that the data have univariate normality.

One prerequisite for multivariate normality testing is to check univariate normality, since this is a necessary, though not sufficient, condition for multivariate normality [61]. Therefore, once the normality of each of the observed variables was confirmed, we tested the hypothesis of multivariate normality as proposed by Mardia [62], [63]. According to [30], Mardia's test is popular in applied research and relies on the normalized value of multivariate kurtosis. This is done by comparing Mardia's coefficient for the data under study with a calculated value based on the formula p (p + 2), where p is the number of variables observed in the model. Khine [64] verified this assumption by contrasting the value of multivariable kurtosis obtained in the SPSS Amos® program with that calculated with the proposed formula. In this study, the calculation was performed by assuming that the instrument had 53 variables. The formula yielded a value of 2,915, whereas the multivariate kurtosis index obtained through SPSS Amos® was 335.8. In other words, since the latter is lower than the former, the multivariate normality assumption was fulfilled in the dataset.

Finally, we tested data multicollinearity to discard that two or more variables were highly correlated and thus measured the same construct [64]. A common practice to test multicollinearity is to calculate the bivariate correlations. In this sense, Kline [57] claims that any pair of variables with a correlation greater than 0.85 should be interpreted as evidence of potential problems; however, when calculating the correlation matrix, we did not find any correlation greater than 0.85. In fact, the highest bivariate correlation obtained was 0.82. Another method to test multicollinearity is to analyze the variance inflation factors (VIFs). If the VIF index of a variable is greater than 10, that variable might be redundant [57]. The indices computed in this research were all lower than 10, with the maximum value of 5.86. In conclusion, according to the results of the two multicollinearity tests, our data set was free from multicollinearity problems.

1) FACTOR ANALYSIS

The exploratory factor analysis (EFA) of the correlation matrix determined the latent dimensions, and its results were used as an indicator of the validity of each construct being studied. According to [65], instrument validity is the degree to which a measuring instrument measures what it really intends to measure or serves the purpose for which it was developed. The first step when conducting an EFA is to assess sample adequacy by calculating the Kaiser Meyer Olkin (KMO) index. The KMO test provides a measure to determine whether the partial correlations between the variables are small. KMO values greater than 0.7 are considered regular, values above 0.8 are meritorious, and values beyond 0.9 are very good [66]. Another method used to determine the feasibility of a factor analysis is Bartlett's sphericity test. It involves testing a null hypothesis that assumes that the matrix of correlations between the analyzed variables is equal to the identity matrix. In this sense, a factor analysis is feasible as long as the null hypothesis is rejected. This study reported a KMO value of 0.981 and a significant Bartlett's sphericity test (p-value <0.01), which confirmed the applicability of the factor analysis. The second important step of an EFA is the removal of non-significant factor loadings. Hair *et al.* [54] suggest that the appropriate value of a factor loading goes in accordance with the sample's size. As previously mentioned, the study is based on 557 reliable surveys; therefore, factor loading values greater than 0.3 were considered as significant for the analysis. In the factor analysis, the maximum likelihood estimation is used to extract the factors and an oblique promax rotation. Factor rotation is essential in EFA. In fact, it is considered by many as the most important tool in the interpretation of EFAs [54]. The rotation can be either orthogonal, assuming that the factors are not correlated, or oblique, if there is correlation between them [57]. In this sense, varimax is a well-known method used for orthogonal rotation [67], whereas promax is widely employed in oblique rotation [68].

In this study, we performed a promax oblique rotation, since the method not only takes into account correlations, but also allows an easier and more substantive interpretation than an orthogonal rotation [30]. Besides, promax oblique rotation was used since there was no basis for assuming that the latent variables should not be correlated. A similar approach was adopted in [69]. Hence, after performing the EFA and using the promax rotation, we identified 11 constructs composed by a total of 53 variables with significant factor loadings. Similarly, we managed to explain 74% of the total variance of the data. Finally, it is worth mentioning that the eigenvalues of all the components were greater than 1. To assess the reliability and consistency of our findings, we followed a confirmatory approach. That is, after performing the EFA, we conducted a confirmatory factor analysis (CFA) using SPSS Amos®, version 23. We tested the multivariate normality and multicollinearity of the data and looked for outliers one more time. Then, we discarded any problem regarding the first two assumptions; however, seven more surveys were removed from the analysis due to the presence of outliers. In conclusion, the subsequent tests were conducted with 550 surveys.

The validity of a measurement model depends on establishing acceptable levels of goodness of fit and finding specific evidence of construct validity. Hair *et al.* [54] claim that the use of three to four indices usually provides adequate evidence of model fit. Similarly, Kline [57] states that at least the following four model fit indices must be estimated when trying to validate a measurement model: the $\chi 2$ statistic, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), and the standardized root mean residual (SRMR). From these two perspectives, it is assumed that researchers must report at least an incremental index and an absolute index, in addition to the $\chi 2$ value and the associated degrees of freedom. Consequently, estimating the $\chi 2$value, the CFI or the Tucker-Lewis index (TLI), and the RMSEA will provide enough information to evaluate a model. Also, to compare models of different complexity, researchers can add the parsimony normed fit index (PNFI).

Fig. 1 below depicts the proposed measurement model.

The CFA was performed with program SPSS Amos®, version 23, according to the results obtained from the EFA. The test results confirm the validity of the measurement model. Table 4 lists the model fit indices estimated to test the validity of the model.

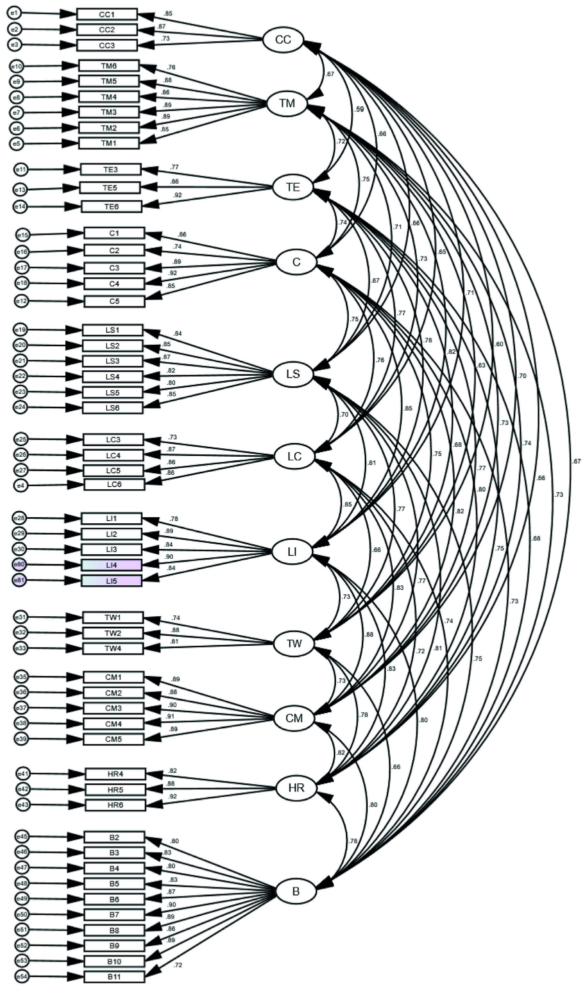

FIGURE 1. **Proposed measurement model.**

TABLE 4. **Model fit indices estimated for the measurement model.**

Goodness of fit statistics	Obtained value	Recommended values for satisfactory model fit to data
$\chi 2$ normalized	2.370	3, 2 or less [59]
TLI	0.937	Greater than 0.9 [54], [60]
CFI	0.942	Greater than 0.9 [54], [60]
RMSEA	0.049	Less than 0.08 [70]

2) CONSTRUCT VALIDITY

Construct validity was measured according to the factor analysis' results. Namely, we assessed convergent, discriminant, and nomological validity as recommended by Hair *et al.* [54]. Table 3 summarizes the CFA test results, whereas the following paragraphs discuss the estimated indices.

TABLE 5. Correlations among constructs, average variance extracted, and squared correlations.

	CC	TM	TE	C	LS	B	LC	LI	TW	CM	HR
CC	**0.67**	0.45	0.35	0.44	0.44	0.45	0.42	0.50	0.36	0.49	0.44
TM	0.67	**0.73**	0.52	0.56	0.50	0.53	0.53	0.67	0.40	0.53	0.55
TE	0.59	0.72	**0.73**	0.55	0.45	0.46	0.59	0.61	0.46	0.59	0.56
C	0.66	0.75	0.74	**0.73**	0.56	0.53	0.58	0.72	0.56	0.67	0.64
LS	0.66	0.71	0.67	0.75	**0.71**	0.56	0.49	0.66	0.59	0.59	0.66
B	0.67	0.73	0.68	0.73	0.75	**0.71**	0.55	0.64	0.44	0.64	0.61
LC	0.65	0.73	0.77	0.76	0.70	0.74	**0.69**	0.72	0.44	0.69	0.52
LI	0.71	0.82	0.78	0.85	0.81	0.80	0.85	**0.73**	0.53	0.77	0.69
TW	0.60	0.63	0.68	0.75	0.77	0.66	0.66	0.73	**0.66**	0.53	0.61
CM	0.70	0.73	0.77	0.82	0.77	0.80	0.83	0.88	0.73	**0.80**	0.67
HR	0.66	0.74	0.75	0.80	0.81	0.78	0.72	0.83	0.78	0.82	**0.76**

Note: Values below the diagonal are correlation estimates among constructs all statistically significant at the 0.001 level, diagonal elements (bolded values) are constructs average variance extracted (AVE) and values above the diagonal are squared correlations.

Convergent validity is popularly measured through the Average Variance Extracted (AVE) index. Usually, any AVE value higher than 0.5 indicates good convergent validity and confirms that a set of items are indicators of a specific construct [54], since they converge or share a high proportion of variance in common. For our study, Table 5 below lists the values of the AVE on the main diagonal of the matrix (bolded) for each construct or latent variable. Note that all the values are higher than 0.5.

On the other hand, we tested the instrument's internal consistency by estimating Cronbach's alpha [71]. This coefficient helps determine whether the different items or questions of a scale are related. Its values range from 0 to 1, being values closer to 1 greater indicators of internal consistency. In this sense, George and Mallery [72] suggest relying on values higher than 0.7, as results below this value would be questionable. According to the results summarized in Table 3, all the latent variables have enough convergent validity, since all the values of Cronbach's alpha are higher than 0.8. These results were obtained through the SPSS 22 program.

Discriminant validity measures the extent to which a construct is truly different from others. Therefore, high discriminant validity provides evidence that a construct is unique and captures some phenomena different from the others. One way to estimate this indicator is by comparing the values of the AVE for one of two constructs with the squared correlation. Then, the AVE must be greater than the squared correlation to confirm that the two constructs are independent of one another. According to Table 5, the constructs have an AVE value greater than the squared of all their correlations, with the exception of two cases, where at least one of the AVE of the constructs is greater than the squared correlation. This corroborates the discriminant validity of the constructs or latent variables.

TABLE 6. Extent of applying CSFs for SS in HEis in Mexico.

CSF	Mean	Very Low	Low	Moderate	High	Very High
CC	**12.70**	sum<4	4≤sum<7	7≤sum<10	10≤sum<13	sum≥13
TM	**24.40**	sum<7	7≤sum<13	13≤sum<19	19≤sum<25	sum≥25
TE	**11.02**	sum<4	4≤sum<7	7≤sum<10	10≤sum<13	sum≥13
LC	**15.57**	sum<5	5≤sum<9	9≤sum<13	13≤sum<17	sum≥17
LI	**19.98**	sum<6	6≤sum<11	11≤sum<16	16≤sum<21	sum≥21
C	**18.68**	sum<6	6≤sum<11	11≤sum<16	16≤sum<21	sum≥21
TW	**9.80**	sum<4	4≤sum<7	7≤sum<10	10≤sum<13	sum≥13
CM	**20.16**	sum<6	6≤sum<11	11≤sum<16	16≤sum<21	sum≥21
HR	**11.19**	sum<4	4≤sum<7	7≤sum<10	10≤sum<13	sum≥13
LS	**21.55**	sum<7	7≤sum<13	13≤sum<19	19≤sum<25	sum≥25
B	**39.71**	sum<11	11≤sum<21	21≤sum<31	31≤sum<41	sum≥41

Finally, nomological validity confirms that the correlations between constructs in a measurement theory make sense. In this sense, the correlation matrix provides information to identify how the constructs relate to each other. The results of the nomological validity test conducted in this research are summarized in Table 5, where all the correlations between the constructs are positive and significant. Such results seem logical, since the constructs were defined according to the successful completion of IPs under an SS project scheme.

D. RESPONSE ANALYSIS

Once the validity of the instrument was verified, an analysis of the responses obtained in the validation stage was carried out to obtain an indicator of the degree of compliance with these factors in a generalized context of Mexican public HEIs. To achieve this, for each of the responses obtained, a sum was made of the evaluations of the items that were grouped into each factor and subsequently averaged to obtain the score that represented the degree to which this said SS factor is addressed during the development of the improvement projects. Additionally, a table of ranges was constructed based on the maximum sum that could be obtained by the factor and divided into five categories. Once the ranges for each category were obtained, the average obtained by the factor was located to obtain its corresponding degree of compliance. These results are shown in Table 6.

According to Table 6, it can be said that the respondents consider that the degree of compliance of these CSFs to the SS methodology during the realization of improvement projects is high. Likewise, the Team Work factor obtained from the point of view of the respondents has a lower degree of compliance, which would represent an area of improvement for HEIs that seeks to implement SS and obtain a maximum benefit from the improvement projects they implement.

V. DISCUSSION

The goal of this research was to design and validate an instrument to assess the implementation of CSFs for SS during the implementation of IPs in HEIs. To this end, we conducted both exploratory and confirmatory factor analyses, as recommended by Hair *et al.* [54], to confirm the validity of the instrument. In fact, factor analysis is usually a viable option for validating questionnaires [73]–[75]. Similarly, the estimated model fit indices confirmed a good fit of the model to the data. One of the primary goals of a CFA is to evaluate the construct validity of a proposed measurement theory. The validity of the construct indicates to what extent the measured elements really reflect the theoretical latent variables that they are intended to measure. Similarly, construct validity has three dimensions: convergent, discriminant, and nomological [54]. In this study, the construct validity test was conducted by estimating the three types of construct validity, and the results were satisfactory in each dimension. Note that a similar approach was adopted by Yu [76], who demonstrated that construct validation is an essential part of the questionnaire validation process.

According to [13], CSFs are fundamental to the continuous improvement initiatives being implemented in the educational domain, especially in higher education. For [13], it is necessary to establish critical success factors and base on them establish actions to minimize risk and maximize the success of continuous improvement strategies. Each of the CSFs should receive constant attention from those responsible for the implementation of methodology since these areas must be functioning correctly so that educational institutions can thrive on continuous improvement. Some of the CSFs that ensure successful improvement projects include top management leadership, linking IPs with the institutional strategy, a customer-oriented focus, and the appropriate selection of human resources [26]. This research analyzes all these CSFs and suggests that they must all receive equal attention from top managers if universities wish to obtain the results desired from IPs; otherwise, their impact on the organization could be lower than that desired.

As mentioned earlier, in the education sector, there have been no studies that report the validation of an instrument that is useful for measuring SS CSFs; however, other instruments exist that have been developed for other sectors, such as the manufacturing industry. For example, the works by [16]–[18], [77] propose an instrument and limit it to their corresponding validation. Unlike previous works, in this investigation, in addition to reporting the validated instrument to evaluate SS CSFs, an analysis of the responses is performed to determine the degree of compliance with the SS factors analyzed in Mexican HEIs. Taking the results of this analysis as a reference, it can be said that the Team Work factor must be reinforced in what corresponds to Mexican HEIs, which is in line with [78] since in that study it is reported that one of the principles of SS to improve the quality of higher education is to emphasize teamwork within the university. The aforementioned could be addressed by providing training to those individuals involved in the improvement projects about the belts system that uses the SS methodology, although the Education and Training factor has been highly evaluated. As mentioned by [79], to count a solid organizational infrastructure led by different SS belts, there would also have to be an adaptation of the belts to the system that universities have, but it would need to help foster teamwork in the realization of IPs. On the other hand, the training of those responsible for executing the improvement projects in the DMAIC methodology would also be very necessary to structure their development and facilitate the achievement of the intended results.

Other studies have conducted similar research; for example, [16] conducted an investigation of the CSFs for the implementation of Lean Six Sigma (LSS) and their impacts on company performance in multinational electronic manufacturing service industries. On the other hand, [17] also conducted a study on a questionnaire that captures the respondent's viewpoint on the CSFs, barriers faced in SS implementation and its impact on the performance measures existing within the manufacturing company. Likewise, [18] conducted an investigation with the objective of presenting the CSFs for the effective implementation of LSS and analyzing the implementation of LSS, focusing on the CSFs identified in the literature, through a survey of companies, geographically dispersed, from both the manufacturing and service industry. Similar studies have been conducted focusing on designing a questionnaire that analyzes the CSFs of SS or LSS in different industries, but no studies have developed one focusing on the higher education sector prior to our work presented here.

VI. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORK

This research attained the goal of designing and validating a surveying instrument to assess the implementation of CSFs for SS during the deployment of IPs in HEIs. However, the two major limitations of the instrument refer to the study population. First, the survey is aimed at Mexican universities, which implies that its administration in other countries must be preceded by a thorough review to address cultural and regional idiosyncrasies. Second, the survey was purposely designed for public universities and might not be suitable for private universities in its original version, since they operate differently [80]. Thus, although the authors think that the instrument could be applied in most HEIs, regardless of whether they are public or private or even perhaps in other organizations within the service sector, it is likely that it is necessary to prove the instrument's validity and, where appropriate, make the necessary adjustments before it is used in organizations other than those in which its validation has been carried out. In relation to the aforementioned limitation, the following aspects are proposed and should be considered for possible lines of future research that intend to make use of the tool proposed here. With regard to the first limitation, the recommendation for future work would be to apply and validate the proposed instrument in another country to check if the results are maintained. Similarly, a second line of research would be to apply and validate the instrument at private universities, since the instrument used in this study was developed in public HEIs. By doing so, it would be verified if the instrument is robust to different types of financing or requires particular settings. An additional possible line for future research would be to incorporate new factors that researchers consider important and relevant into the instrument proposed here.

VII. CONCLUSION

Nowadays, public universities experience economic constraints, as government agencies grant them tight budgets that barely cover their needs. Similarly, service quality in this type of HEIs is not always consistent with customer needs and expectations. Such issues highlight the importance of implementing effective strategies to improve both academic and administrative process. In this sense, the challenge is to strengthen administrative structures with quality assurance systems that would increase resource efficiency, especially during economically restricted periods, without compromising service quality. Improvement projects can also be helpful as a continuous improvement strategy. Moreover, they are a fundamental part of the SS methodology; however, their success depends on the implementation of a series of CSFs, which must be prioritized. Namely, CSFs must become a habitual practice among IP developers in HEIs, as their adequate measurement will allow universities to detect potential improvement opportunities in their processes under an SS reference framework.

The findings confirm that our survey, which is composed of 11 constructs and 53 items, is a valid instrument and can successfully assess the attention given to CSFs for SS during the deployment of IPs in HEIs. Therefore, the survey can be used to detect areas of opportunity when deploying IPs under the SS approach. As previously mentioned, the implementation of CSFs for SS improves the likelihood of IPs to impact on administrative and academic processes in a positive way. In turn, adequate university processes gain relevance at a national performance level, since HEIs play an important role in social development [81]. In other words, universities contribute to the creation of leaders, the advancement of technology, and a nation's economic development.

In both the manufacturing and the services industry, SS is an approved methodology for productivity and competitiveness improvement. Its implementation has reported meaningful benefits, such as higher customer satisfaction and service/process quality, better data-based decision making, and better infrastructure, equipment, and financial benefits. Therefore, SS in HEIs can be applied as a basis to develop IPs while seeking to obtain the same benefits. Some current studies have successfully demonstrated the impact of SS projects in HEIs, yet the literature is still scarce. However, Antony [26] suggests that those universities willing restructure IPs must initiate SS implementation in administrative processes, and then move to academic processes. Moreover, IP developers should be trained in the DMAIC methodology, since its five stages are part of the whole improvement process of SS.

DISCLOSURE STATEMENT

The authors declare no potential conflicts of interest with respect to the publication of this paper.

NOTE

The instrument in its full version can be provided upon request to the corresponding author.

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