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Factores de efectividad en equipos de trabajo Seis Sigma: cuestionario validado por juicio de expertos

Six Sigma Work Team Effectiveness Factors: Questionnaire Validated by Expert Judgment

Fatores de Efetividade da Equipe de Trabalho Seis Sigma: Questionário Validado por Julgamento de Especialistas

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Resumen

Esta investigación presenta el procedimiento para validar un cuestionario/instrumento de medida (IM) por medio de juicio de expertos, el IM fue diseñado a partir de la identificación de factores o criterios a través de una revisión sistemática de literatura. Así, se determinaron 54 factores, los cuales se discriminaron con la aplicación de un Meta Análisis que permitió reducirlos a 29. Posteriormente, un grupo de cinco profesionales expertos en equipos de trabajo y Seis Sigma evaluaron el cuestionario a partir de dos criterios: calidad y coherencia. Los resultados indican que, en una escala del uno al cuatro, al 52.6 % de los ítems se les evaluó con calificación de 4. Luego, a través del análisis estadístico de Friedman se confirmó el desacuerdo para los dos criterios evaluados. En consecuencia, el instrumento de medición fue revisado, mejorado y aplicado a otro grupo de cuatro expertos, por lo que se repitió la prueba de Friedman y en la segunda evaluación se obtuvo un valor de P mayor que 0.05. Por tanto, se concluye que existe acuerdo entre los expertos por los 29 ítems del IM y que este es válido (adecuado), de ahí que se pueda continuar con su aplicación.

Palabras clave: validación de instrumento de medición, juicio de expertos, validación de contenido, factores, Seis Sigma.

Abstract

This research presents the validation of a Questionnaire-type Measurement Instrument (MI) through expert judgment, the IM was designed from the identification of criteria or factors through a Systematic Literature Review, determining 54 factors, which as they were discriminated by Meta-Analysis, reducing to 29 factors. Subsequently, a group of five professional experts in Work Teams and Six Sigma evaluated the questionnaire on two criteria: quality and coherence. The results show that, on a scale from one to four, 52.6% of the items were evaluated with a grade of four. Subsequently, through Friedman's statistical test, the disagreement was confirmed for the two criteria evaluated; then, the measurement instrument was reviewed, improved and applied to another group of four experts, repeating the Friedman test and obtaining a P value greater than 0.05 in the second evaluation, concluding that there is agreement between the experts on the 29 items of the MI and that it is valid (adequate) so it may be used can be continued.

Keywords: Measurement Instrument Validation, Expert Judgment, Content Validation, Factors, Six Sigma.

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Resumo

Esta investigação apresenta a validação de um Instrumento de Medida (IM) do tipo Questionário por meio do julgamento de especialistas, a MI foi elaborada a partir da identificação de critérios ou fatores através de uma Revisão Sistemática da Literatura, determinando 54 fatores, que ao serem discriminados por Metanálise, reduzindo-se para 29 fatores. Posteriormente, um grupo de cinco profissionais especialistas em Equipes de Trabalho e Seis Sigma avaliou o questionário em dois critérios: qualidade e coerência. Os resultados mostram que, em uma escala de um a quatro, 52,6% dos itens foram avaliados com nota quatro. Posteriormente, por meio do teste estatístico de Friedman, confirmou-se a discordância para os dois critérios avaliados; em seguida, o instrumento de medida foi revisado, aprimorado e aplicado em outro grupo de quatro especialistas, repetindo-se o teste de Friedman e obtendo-se um valor de P maior que 0,05 na segunda avaliação, concluindo-se que há concordância entre os especialistas nos 29 itens da MI e que o mesmo é válido (adequado) para que possa ser utilizado continuado

Palavras-chave: Validação de Instrumentos de Medição, Opinião Especializada, Validação de Conteúdo, Fatores, Seis Sigma.

Fecha Recepción: Marzo 2023 **Fecha Aceptación:** Enero 2024

Introduction

Companies apply the Six Sigma (SS) methodology with the objective of improving operations through the use of statistical tools in quality management (Goh and Xie, 2004), since it the reduction of process variability and elimination of activities that do not add value (Bañuelas *et al.*, 2005; Rodríguez-Medina *et al.* , 2021). In the industrial practice, this methodology is implemented through projects led by work teams (Lloréns-Montes and Molina, 2006), and it is fundamental for success. However, despite its wide use, some literature reports that are lower than those projected, so it is pertinent to examine the literature to identify and evaluate results of benefits are success factors and determine their relative importance.

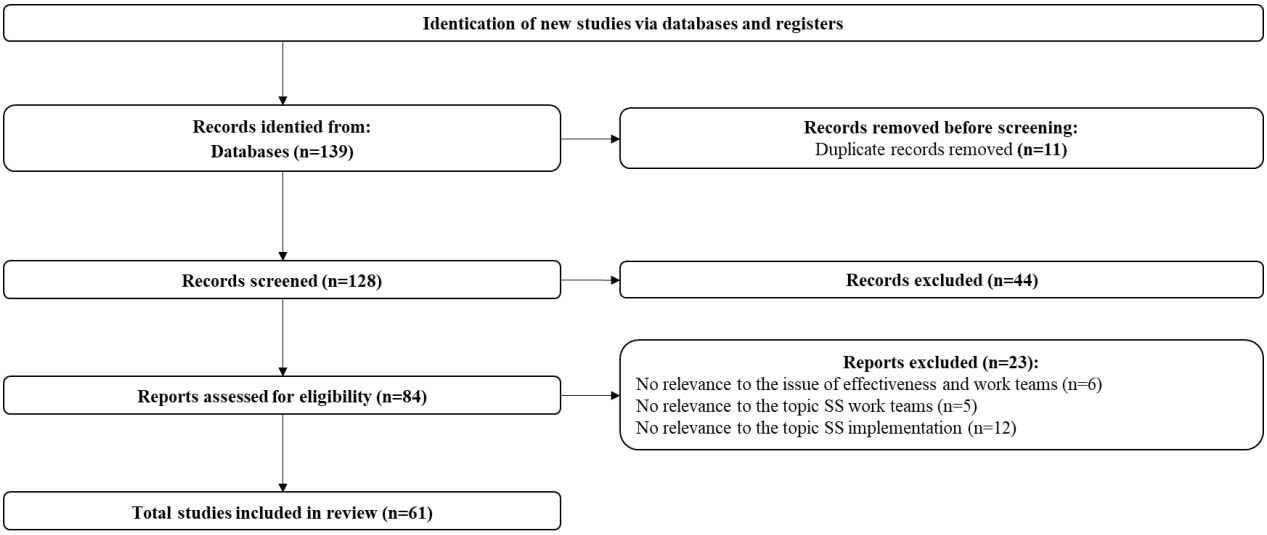
This work, therefore, focuses on the validation of a measurement instrument (MI) in the form of a questionnaire through the judgment of a group of experts, which will be used to collect data for the development of a predictor model of the effectiveness of work teams in projects that apply the SS methodology.

Critical Success Factors (CSF) are variables, characteristics or conditions that significantly affect the success of organizational projects (Milosevic and Patanakul, 2005), represent areas of

interest so that those responsible can implement effective measures for the project administration, focusing attention on those factors and make informed decisions (Suárez and Díaz, 2013).

During the research phase, are identified effectiveness factors of SS work teams in manufacturing industry projects. To do this, a search was carried out for scientific articles (figure 1) published between 2017 and 2021, this literature is analyzed by the PRISMA methodology.

Figure 1. PRISMA Diagram for Systematic Literature Review



Source: Valles Chávez *et al.* (2023)

In total, a total of 139 articles were reviewed, of which 61 were selected. The remainder were excluded as they were considered not relevant, obtaining a list of 54 factors These articles were studied through Meta-Analysis to determine factors that contribute to the success of SS projects and their relationship with the effectiveness of the work team. Table 1 presents the 29 factors.

Table 1. Factors identified by Meta-Analysis.

No.	Factor	Frequency
1	Management participation *	20
2	Senior management commitment	5
3	Organizational infrastructure	15
4	Cooperation, effective communication and internal transmission.	13
5	Cultural change management (resistance to change)	6
6	Strategic planning	8
7	Project prioritization and selection	12
8	Selection, monitoring and review of the SS project	6
9	Alignment of the SS project with the organization's objectives	5
10	Integration of SS to financial benefits	5
11	Link SS with clients *	19
12	Link SS with suppliers	10
13	Linking SS with human resources management	6
14	Performance recognition program	7
15	Approach based on short and long term objectives	7
16	Investment of adequate resources	9
17	Tools and techniques of the SS methodology	12
18	System adaptable to the implementation of SS	6
19	Metric-Focused SS	6
20	Data analysis system and statistical methods	9
21	Coordination with management systems and knowledge exchange	7
22	Training and continuous training of specialized multifunctional teams	15
23	Project leader selection	7
24	SS methodology role structure	5
25	Collaborative team	11
26	Teamwork	11
27	Participation and empowerment of members of the SS work team	9
28	Synergy between senior management and the SS project work team	9
29	Executive leadership skills	9

Source: Valles Chávez *et al.* (2023)

Measurement is a procedure used to link abstract concepts, identified as assumed constructs or latent variables. To measure these concepts, it can only be done through observable variables (Cupani, 2012), which is achieved through a measurement instrument (MI) in the form of a questionnaire, understood as the resource that researchers use to record data and generate information of the research variables.

It is a set or series of questions about one or several variables to be measured. Therefore, the MI must meet three essential requirements: be Objectivity, Validity and Reliability (Hernández Sampieri *et al.* , 2014). Objectivity refers to the level to which MI is influenced by tendencies and

biases that could be generated by the researchers who manage, rate, and interpret it. To reinforce the objectivity of the IM, its standardized application is recommended, that is, with the same instructions and conditions for all judges, as well as in the evaluation of results. Furthermore, it is suggested that the MI be administered by personnel with knowledge, training and experience.

Validity is described as the degree to which an MI effectively measures the desired variable. The literature reports three approaches to validity: content-related, criterion-based, and construct-related. In this instrument, validity is understood as the degree to which the MI measures the variable in question according to the expert's criteria.

Reliability refers to the level at which the MI provides consistent results, revealing the degree of confidence. This means that, if applied repeatedly, similar results should be obtained (Mondy and Noe, 2005). It is important to note that even if an MI is reliable, it is not necessarily valid. Therefore, it is necessary to demonstrate both reliability and validity to guarantee the certainly of the results (Hernández Sampieri *et al.* , 2014).

For the validation of the MI, the data is analyzed using non-parametric statistics such as the Friedman test, which, according to Granato *et al.* (2014), is presented as an alternative to analyze the variance between two factors.

Methodology

The methodology used in this research was quantitative, since data was collected for hypothesis testing, based on numerical measurement and the use of statistical analysis. This approach involves a series of research processes that range from the collection, analysis, integration and discussion of quantitative data with the objective of obtaining a greater understanding of the phenomenon studied through the inference of the results of the information obtained (Malhotra, 2008; Hernández Sampieri *et al.* , 2014).

Materials

For this research, articles and publications available in various databases selected for their recognition and informative quality were used, as well as the number of articles found, such as Springer, Sciencedirect , IEEE, Elsevier, Emerald , among others, during the period between 2017 and 2021, also including publications from previous years. To evaluate the factors, an MI was designed in the form of a questionnaire, derived from the systematic review of literature and the application of Meta-Analysis. Statistical data analyzes were carried out with Minitab® version 18.

Methods

Following a procedure similar to previous studies (García Martínez *et al.*, 2021; Rodríguez Medina *et al.*, 2021), and given that the measurement seeks to establish relationships between abstract concepts and empirical data that record information about variables, the MI records observable data representing the concepts or variables of the study. This research was planned in three steps: identification of factors, design of the IM, and validation of the IM by expert judgment (Figure 2).

Figure 2. Methodology for validation of the MI

Source: self-made

The first step consisted of identifying the factors that impact the effectiveness of Six Sigma (SS) teams through a literary review of the state of the art and consultation with expert advisors in the application of the SS methodology. In this way, a first approximation to the critical factors that should be included in the MI was achieved.

In the second step, the MI was designed based on the information obtained and considering the 29 factors identified by the Meta-Analysis. The items to be included in the questionnaire were written, and a draft was prepared. For this purpose, the operationalization of constructs was carried out, which is a theoretical concept used to define relationships (Hair *et al.* , 1999). As a result, 7 constructs were obtained, which are presented in Table 2.

Table 2. Operationalization of constructs

No.	Construct	Definition
1.	Project leader	It seeks to determine to what extent the project leader is one of the most important factors for the effectiveness of the SS work team.
2.	Six Sigma Project Team	It seeks to determine some indicators that an SS project work team should know.
3.	Organizational infrastructure	It mainly seeks to determine the resources and organizational structure necessary for the project to be immersed in an organization that gives it the necessary support.
4.	Top Management	It seeks to determine the commitment and participation of senior management for and adequate deployment of a SS project and to assure the adequate selection and prioritization of the project.
5.	Customer and supplier integration	Seeks to determine the connection of the organization's commercial strategy with its customers and suppliers
6.	Six Sigma project management	Seeks to determine the adequate planning, monitoring and measurement of the SS project, as well as the performance of the tools and techniques implemented
7.	Deployment of the Six Sigma project	It seeks to determine the administrative elements that management must consider that foster an adequate environment for the implementation of the project.

Source: self-made

Finally, in the third step, the validation of the content of the MI was carried out using the judgment method of experts on the subject. The collaboration of a group of experts was requested to evaluate the IM in terms of clarity and coherence, accordingly to the methodology proposed by Escobar-Pérez and Cuervo-Martínez (2008). In this research, the two categories mentioned above are evaluated, taking advantage of the results of the Meta-Analysis (MA) as evidence to integrate the findings of several previous studies.

The validation by expert judgment (EJ) was carried out using non-parametric tests, because nominal data are used. To determine differences in center location (median) and test the analysis recursively with three or more dependent samples (Granato *et al.* , 2014), the Friedman statistical test is applied to determine the level of agreement between the experts and calculate the P value, thus discriminating between the two hypotheses in relation to the data collected.

H_0 : There is significant agreement among the experts.

H_1 : There is no significant agreement among the experts.

In addition, two researchers from the Department of Industrial and Manufacturing Engineering at IIT-UACJ were asked to review the list of items proposed for the IM and provide comments on it.

Results

To evaluate the impact of these factors, an initial list of items was prepared to be included in the draft of the MI, which included seven criteria and preliminary twenty-nine conditions to be evaluate measure (Table 3).

Table 3 . Items for the IM draft

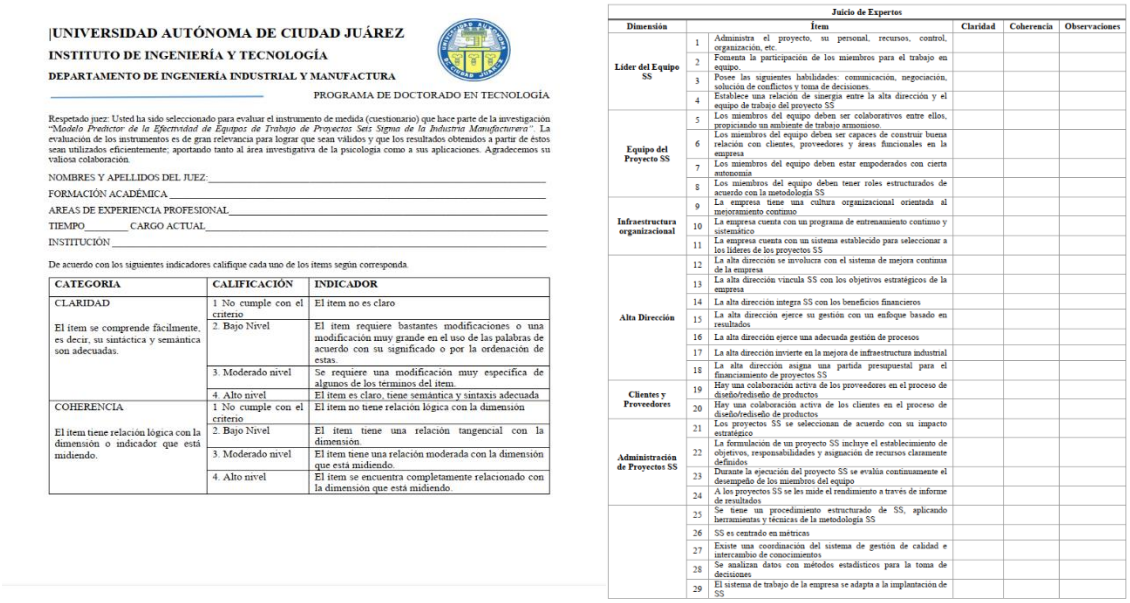
Dimension	Item	
SS Team Leader	1	Manage the project, its personnel, resources, control, organization, etc.
	2	Encourages member participation for teamwork.
	3	Has the following skills: negotiation, communication, decision making and conflict resolution.
	4	Establishes a synergistic relationship between senior management and the SS project work team
SS Project Team	5	Team members must be collaborative among themselves, fostering a harmonious work environment.
	6	Team members have the ability to build good relationships with clients, suppliers and functional areas in the company.
	7	Team members must be empowered with some autonomy
	8	Team members must have roles structured according to the SS methodology
Organizational infrastructure	9	The company has an organizational culture aimed at continuous improvement
	10	The company has a continuous and systematic training program
	11	The company has an established system to select leaders for SS projects
High direction	12	Senior management is involved with the company's continuous improvement system
	13	Senior management links SS with the company's strategic objectives
	14	Senior management integrates SS with financial benefits
	15	Senior management exercises its management with a results-based approach
	16	Senior management exercises adequate process management
	17	Senior management invests in improving manufacturing infrastructure
	18	Senior management assigns a budget to finance SS projects
Clients and suppliers	19	There is active collaboration of suppliers in the product design and/or redesign process
	20	There is active customer collaboration in the product design/redesign process
SS Project Management	21	SS projects are selected according to their strategic impact
	22	The formulation of an SS project includes the establishment of clearly defined objectives, responsibilities and allocation of resources.
	23	During the execution of the SS project, the performance of team members is continually evaluated.
	24	Performance of SS projects is measured through a results report
SS project deployment	25	There is a structured SS procedure, applying tools and techniques of the SS methodology

	26	SS is metrics-centered
	27	There is coordination of the quality management system and knowledge exchange
	28	Data is analyzed with statistical methods for decision making
	29	The company's work system adapts to the implementation of SS

Source: self-made

The result of the second step (in IM design) was the preparation of the IM that was presented to the expert evaluators, starting from the previously prepared list and taking into account the comments and adjustments (figure 3).

Figure 3. Measuring Instrument for Validation by Expert Judgment



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PROGRAMA DE DOCTORADO EN TECNOLOGÍA

Respetado juez: Usted ha sido seleccionado para evaluar el instrumento de medida (cuestionario) que hace parte de la investigación "*Modelo Predictor de la Efectividad de Equipos de Trabajo de Proyectos Seis Sigma de la Industria Manufacturera*". La evaluación de los instrumentos es de gran relevancia para lograr que sean válidos y que los resultados obtenidos a partir de éstos sean utilizados eficientemente; aportando tanto al área investigativa de la psicología como a sus aplicaciones. Agradecemos su valiosa colaboración.

NOMBRES Y APELLIDOS DEL JUEZ:
FORMACIÓN ACADÉMICA
AREAS DE EXPERIENCIA PROFESIONAL
TIEMPO CARGO ACTUAL
INSTITUCIÓN

De acuerdo con los siguientes indicadores califique cada uno de los items según corresponda.

CATEGORIA	CALIFICACIÓN	INDICADOR
CLARIDAD El ítem se comprende fácilmente, es decir, su sintáctica y semántica son adecuadas.	1. No cumple con el criterio	El ítem no es claro
	2. Bajo Nivel	El ítem requiere bastantes modificaciones o una modificación muy grande en el uso de las palabras de acuerdo con su significado o por la ordenación de estas.
	3. Moderado nivel	Se requiere una modificación muy específica de algunos de los términos del ítem.
	4. Alto nivel	El ítem es claro, tiene semántica y sintaxis adecuada
COHERENCIA El ítem tiene relación lógica con la dimensión o indicador que está midiendo.	1. No cumple con el criterio	El ítem no tiene relación lógica con la dimensión
	2. Bajo Nivel	El ítem tiene una relación tangencial con la dimensión.
	3. Moderado nivel	El ítem tiene una relación moderada con la dimensión que está midiendo.
	4. Alto nivel	El ítem se encuentra completamente relacionado con la dimensión que está midiendo.

Juicio de Expertos

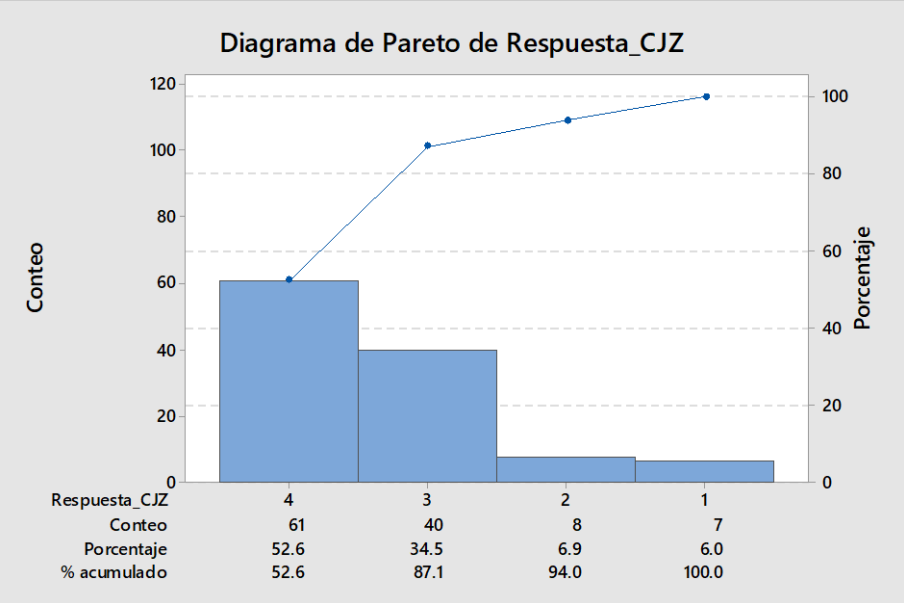
Dimensión		Ítem	Claridad	Coherencia	Observaciones
Líder del Equipo SS	1	Administra el proyecto, su personal, recursos, control, organización, etc.			
	2	Fomenta la participación de los miembros para el trabajo en equipo.			
	3	Posee las siguientes habilidades: comunicación, negociación, solución de conflictos y toma de decisiones.			
	4	Establece una relación de sinergia entre la alta dirección y el equipo de trabajo del proyecto SS			
Equipo del Proyecto SS	5	Los miembros del equipo deben ser colaborativos entre ellos, propiciando un ambiente de trabajo armonioso.			
	6	Los miembros del equipo deben ser capaces de construir buena relación con clientes, proveedores y áreas funcionales en la empresa			
	7	Los miembros del equipo deben estar empoderados con cierta autonomía			
	8	Los miembros del equipo deben tener roles estructurados de acuerdo con la metodología SS			
Infraestructura organizacional	9	La empresa tiene una cultura organizacional orientada al mejoramiento continuo			
	10	La empresa cuenta con un programa de entrenamiento continuo y sistemático			
	11	La empresa cuenta con un sistema establecido para seleccionar a los líderes de los proyectos SS			
Alta Dirección	12	La alta dirección se involucra con el sistema de mejora continua de la empresa			
	13	La alta dirección vincula SS con los objetivos estratégicos de la empresa			
	14	La alta dirección integra SS con los beneficios financieros			
	15	La alta dirección ejerce su gestión con un enfoque basado en resultados			
	16	La alta dirección ejerce una adecuada gestión de procesos			
	17	La alta dirección invierte en la mejora de infraestructura industrial			
	18	La alta dirección asigna una partida presupuestal para el financiamiento de proyectos SS			
Clientes y Proveedores	19	Hay una colaboración activa de los proveedores en el proceso de diseño/rediseño de productos			
	20	Hay una colaboración activa de los clientes en el proceso de diseño/rediseño de productos			
Administración de Proyectos SS	21	Los proyectos SS se seleccionan de acuerdo con su impacto estratégico			
	22	La formulación de un proyecto SS incluye el establecimiento de objetivos, responsabilidades y asignación de recursos claramente definidos			
	23	Durante la ejecución del proyecto SS se evalúa continuamente el desempeño de los miembros del equipo			
	24	A los proyectos SS se les mide el rendimiento a través de informe de resultados			
	25	Se tiene un procedimiento estructurado de SS, aplicando herramientas y técnicas de la metodología SS			
	26	SS es centrado en métricas			
	27	Existe una coordinación del sistema de gestión de calidad e intercambio de conocimientos			
	28	Se analizan datos con métodos estadísticos para la toma de decisiones			
	29	El sistema de trabajo de la empresa se adapta a la implantación de SS			

Source: self-made

In the third step, which corresponds to the validation of the IM by experts, a total of five specialists were selected, who had to meet three criteria: have at least five years of work experience, have a doctorate degree in engineering or a related field, have as academic training and experience in SS topics. These experts evaluated the instrument in two different categories: clarity and coherence. During this step, one expert's responses were discarded due to inconsistencies.

In an initial exploration of the two criteria, the results of the evaluations showed that, of the 232 assignments of a value to the items, the judges agreed in assigning a value of 4 52.6% of the time and a value of 3 in 34.5%. These results empirically show a disagreement between the judges (figure 4).

Figure 4. Pareto initial exploration of item evaluation by the experts



Source: self-made

For example, in the *clarity criterion* , the experts (A, B, C, D) established a value between 1 and 4 for each item, according to their appropriate consideration (table 4).

Table 4. Evaluation of the *clarity criterion* by JE

Item/expert	A	B	C	D		Item/expert	A	B	C	D
1	3	3	3	3		16	4	1	3	3
2	3	4	4	3		17	4	1	3	4
3	4	4	4	3		18	4	1	4	4
4	4	4	4	2		19	4	1	3	4
5	4	4	3	3		20	4	2	3	4
6	4	4	3	2		21	4	3	3	3
7	4	4	2	2		22	4	4	3	3
8	4	3	4	3		23	4	2	3	4
9	3	3	3	3		24	3	3	2	3
10	4	4	4	3		25	4	4	4	4
11	4	4	4	2		26	4	4	4	3
12	4	4	4	3		27	3	1	4	3
13	4	4	4	3		28	4	1	4	4
14	4	4	3	3		29	4	1	3	3
15	4	4	4	3						

Source: self-made

Subsequently, the data presented in Table 5 were statistically analyzed with *software* Minitab, version 18, using the statistic Friedman. In this phase the following hypotheses were proposed :

H_0 : The treatment effects are equal to zero.

H_1 : Not all treatment effects are equal to zero.

Table 5. Friedman test of the *clarity criterion* (Minitab* results)

Treatment_Cjz	N	Median	Sum of classifications
1	29	3.75	91.0
2	29	3.50	68.0
3	29	3.50	73.5
4	29	3.25	57.5
General	116	3.50	
Method	G.L.	Chi-square	p value
Not adjusted for ties	3	12.18	0.007
Adjusted for ties	3	18.68	0.000

Source: self-made

Also, the Friedman statistical test was performed for the *coherence criterion*. Table 6 shows the results for S (adjusted for ties).

Table 6. Friedman statistical test for the *clarity* and *coherence criteria*

	Clarity	Coherence
Statistician S	14.41	75
G.L.	3	3
P value	0.000	0.000

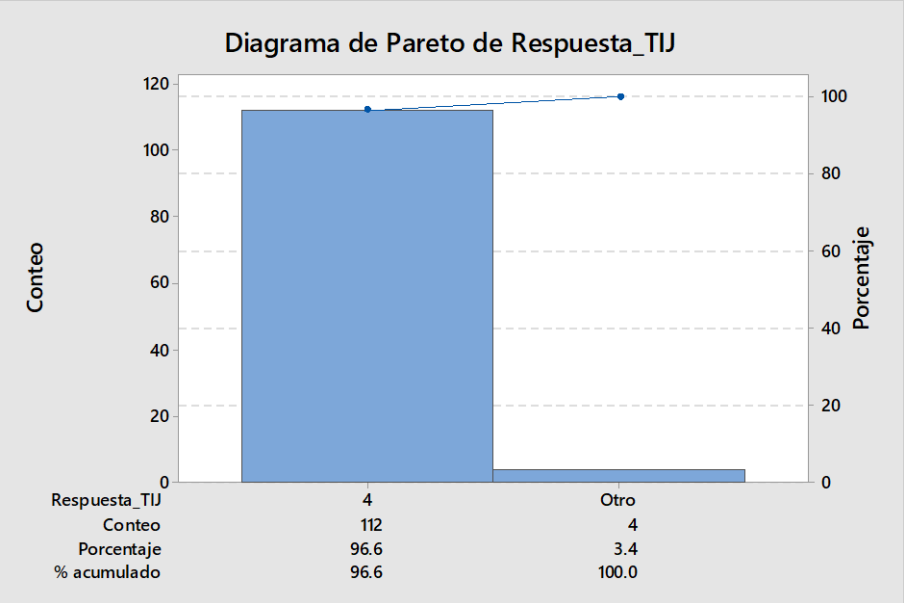
Source: self made

Table 6 shows that the results of the statistical data analysis reveal that for both the clarity and coherence criteria, the test statistic S has a P value less than the alpha value of 0.050 (which is not adjusted for ties), therefore, there is sufficient evidence to reject the null hypothesis (H_0). In both criteria, the hypothesis that treatment effects are equal to zero is refuted by the data. In other words, there is no agreement among experts on the elements under analysis. Due to this, a review of the questionnaire is required, and improvements are made to these criteria.

Discussion of results

After the first review, a second evaluation is carried out with 4 different experts than the first. Again, both criteria (clarity and coherence) are evaluated. In this case, the S test statistic had a P value greater than the alpha value of 0.05 (not adjusted for ties), indicating that there is insufficient evidence to reject the null hypothesis (H_0). For example, in the clarity criterion, the S value was 0.33 and the P value was 0.954, which means that there is agreement between the experts.

Figure 5. Results of the second evaluation of the items by JE



Source: self made

Figure 5 shows that 96.6% of the items were evaluated with a score of 4, which allows us to conclude that, as there is agreement between the experts, the MI is valid for its application. Empirically, this research work reflects that 96.6% of the items received an assigned rating of 4, considered the highest value on a scale from 1 to 4. The Friedman test used for statistical analysis confirms the agreement between the expert evaluators. Therefore, the questionnaire (annex) is considered valid to measure the effectiveness factors of work teams in Six Sigma projects (Álvarez *et al.* , 2021).

Finally, when the criteria to be evaluated are specified with a systematic literature review, validation by expert judgment is applied and statistical analysis is used, such as the Friedman test, it can be stated that it is possible to achieve validation of an instrument more efficient measurement.

Conclusions

This research was based on the assumption that the lack of a validated and reliable measurement instrument (MI) could have a negative impact on the identification and quantification of the critical factors of Six Sigma (SS) teamwork effectiveness. This objective is considered fulfilled, since an MI has been developed in the form of a formal questionnaire, which facilitates its use for both SS practitioners and academia and has been appropriately validated by expert judgment.

It is important to highlight that, in the stage of selecting experts to participate in the evaluation of the MI, it is crucial that they have knowledge of the theory and practice of SS. Furthermore, it is recommended to define in advance the number of participating experts in relation to the characteristics of the test and the statistical analysis to be applied.

A limitation of this research work is that the first validation of the MI by expert judgment was carried out in person, while the second evaluation was carried out virtually, so the results should not be generalized. However, since the stages and results have been presented clearly and concisely in the validation method, this procedure can be applied for the development of instruments.

Future lines of research

This work is part of the second stage of the research project aimed at developing a predictive model for the effectiveness of work teams in Six Sigma projects. Therefore, the next step will focus on the evaluation of the reliability, or internal consistency, of the measurement instrument (MI) using Cronbach's alpha coefficient in a pilot run. This will be carried out by taking a sample of the target population. In addition, the application of factor analysis and structural equation modeling is contemplated.

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References

Álvarez, M., Valles, A. and Noriega, S. (2021). *Six Sigma Projects Work Teams: A Literature Review of the Factors Influencing Their Effectiveness* . In Proceedings of the 10th Annual World Conference of the Society for Industrial and Systems Engineering.

Bañuelas, R., Antony, J. and Brace, M. (2005). An application of Six Sigma to reduce waste. *Quality and Reliability Engineering International, 21* (6), 553–570. https://doi.org/10.1002/qre.669

Cupani, M. (2012). Analysis of structural equations: concepts, stages of development and an example of application. *Thesis Magazine, 1*, 186–199. http://www.revistas.unc.edu.ar/index.php/tesis/article/download/2884/2750

Escobar-Pérez, J. and Cuervo-Martínez, Á. (2008). Content validity and expert judgment: an approach to its use. *Advances in Measurement , 6* (September), 27–36.

García Martínez, R., Poblano-Ojinaga, ER, Reyes Valenzuela, R., Cuamea Cruz, G. and Juárez Rodríguez, R. (2021). Career choice and higher education institution: validation of measurement instrument through structural equation modeling. *RIDE Ibero-American Journal for Educational Research and Development, 11* (22). https://doi.org/10.23913/ride.v11i22.961

Goh, T.N., & Xie, M. (2004). Improving on the six sigma paradigm. *The TQM Magazine, 16* (4), 235–240. https://doi.org/10.1108/09544780410541882

Granato, D., De Araújo Calado, VM and Jarvis, B. (2014). Observations on the use of statistical

methods in Food Science and Technology. *Food Research International*, *55*, 137–149. https://doi.org/10.1016/j.foodres.2013.10.024

Hair, J.F., Anderson, R.E., Tatham, R.L., & Black, W.C. (1999). *Multivariate analysis. Iberia* Hall.

Hernández Sampieri, R., Fernández Collado, C. and Baptista Lucio, P. (2014). *Research methodology* (6th ed .). McGraw-Hill.

Lloréns-Montes, FJ and Molina, LM (2006). Six Sigma and management theory: Processes, content and effectiveness. *Total Quality Management & Business Excellence* , *17* (4), 485–506. https://doi.org/10.1080/14783360500528270

Malhotra, N. K. (2008). Market research. In P. Education (ed.), *Market Research* (Vol. 3, Number 6). https://repository.uaeh.edu.mx/revistas/index.php/xikua/article/view/1314

Milosevic, D. and Patanakul, P. (2005). Standardized project management may increase development projects success. *International Journal of Project Management* , *23* (3), 181–192. https://doi.org/10.1016/j.ijproman.2004.11.002

Mondy, R.W. and Noe, R.M. (2005). *Human resources management* . Pearson Education of Mexico SA de CV

Rodríguez Medina, MA, Poblano-Ojinaga, ER, Alvarado Tarango, L., González Torres, A. and Rodríguez Borbón, MI (2021). Validation by expert judgment of an evaluation instrument for evidence of conceptual learning. *RIDE Ibero-American Journal for Educational Research and Development* , *11* (22). https://doi.org/10.23913/ride.v11i22.960

Rodríguez-Medina, MA, Poblano-Ojinaga, ER, Rodríguez-Borbón, MI and Alvarado-Tarango, L. (2021). A high impact business strategy: The Six Sigma methodology. *Dyna* , *96* (2), 128. https://doi.org/10.6036/10010

Suárez, A. and Díaz, J. (2013). *Critical success factors in Venezuelan university research* .

Valles Chávez, A., Alvarez Argüelles, M., and Torres Argüelles, SV (2023). Critical success factors in the deployment of six sigma projects: a systematic review and meta-analysis. In J. Pinto, J. Rodríguez, E. and H. Sohn (coords.), *Approaches and methods to solve social and productive problems in a sustainable way* (pp. 69–91). CENID Publishing.

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