Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Scientific articles

Validez de contenido de un instrumento de medición para medir el éxito en la implementación del TPM

Content validity of a measurement instrument to measure success in TPM implementation

Validade de conteúdo de um instrumento de medição para medir o sucesso na implementação do TPM

Paola Fernanda Castillo Salcido
Universidad Autónoma de Juárez, México
al209505@alumnos.uacj.mx
https://orcid.org/0000-0001-5481-186X

Rafael García Martínez
Tecnológico Nacional de México, Instituto Tecnológico de Hermosillo, México
rafael.garciam@hermosillo.tecnm.mx
https://orcid.org/0000-0001-7175-5361

Jesús Andrés Hernández Gómez
Universidad Autónoma de Ciudad Juárez, México
jhernand@uacj.mx
https://orcid.org/0000-0003-2325-2051

Eduardo Rafael Poblano Ojinaga
Tecnológico Nacional de México/ I T de Ciudad Juárez, México
e_poblano@yahoo.com
https//orcid.org/0000-0003-3482-7252

Salvador A. Noriega Morales
Universidad Autónoma de Ciudad Juárez, México
snoriega@uacj.mx
https://orcid.org/0000-0001-7813-5835

Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Resumen

La validación de contenido constituye una etapa crítica y compleja en el proceso de desarrollo de instrumentos de medición comúnmente empleados para evaluar constructos complejos en la investigación social y administrativa, ya que debe asegurarse que los ítems o variables medibles de cada constructo sean representativos. Por eso, el objetivo de esta investigación fue reportar y discutir la validación de contenido de manera práctica de un instrumento de medición que evalúa el éxito en la implementación del mantenimiento productivo total (TPM, por sus siglas en inglés) a partir de cinco constructos: participación y compromiso de la gerencia (MPC), educación y capacitación (ET, por sus siglas en inglés), involucramiento del personal (SI, por sus siglas en inglés), cambio de cultura organizacional (COC) y éxito en la implementación del TPM (STPM, por sus siglas en inglés). Para llevar a cabo el procedimiento de validación se empleó el método de juicio de expertos y el índice de contenido de Lynn (I-CVI), así como una revisión de literatura, y recopilación y formulación de ítems que conforman los constructos, los cuales fueron validados mediante el juicio de expertos, quienes examinaron las dimensiones de relevancia, coherencia y claridad de los ítems. Las respuestas de los expertos fueron analizadas utilizando el método del índice de validez de contenido de Lynn (I-ICV, S-CVI/ave, S-CVI/UA) para cada ítem en cada una de las dimensiones. Los resultados muestran que los ítems son representativos del constructo correspondiente, lo que indica que el instrumento posee una validez de contenido muy alta con un nivel de significancia del 5%. Como resultado, se presenta un instrumento con validez de contenido para medir el éxito de la implementación del TPM a través de los cuatro constructos propuestos.

Palabras claves: validez de contenido, juicio de expertos, mantenimiento total productivo (TPM), factores críticos de éxito (FCE).

Abstract

Content validation is a critical and intricate stage in the process of developing measurement instruments often used to assess complex constructs in social and administrative research. Measurement instruments must exhibit content validity to ensure that the measurable items or variables for each construct are representative of those constructs. This study aims to report and discuss the practical content validation of a measurement instrument that assesses success in the implementation of Total Productive Maintenance (TPM) considering five constructs: Management Participation and Commitment (MPC), Education and Training

(ET), Staff Involvement (SI), Organizational Cultural Change (COC), and Success in TPM implementation (STPM).

For the validation procedure, the expert judgment method and Lynn's Content Validity Index (I-CVI) were utilized, involving a literature review, item collection, and formulation for the constructs. These were validated by expert judgment, where they assessed item dimensions: relevance, coherence, and clarity. Expert responses were analyzed using Lynn's Content Validity Index (I-CVI, S-CVI/ave, S-CVI/UA) method for each item within the dimensions. Results show that the items are representative of their corresponding construct, thus establishing the instrument's high-level content validity with a significance level of 5%. The outcome is a content valid instrument to measure TPM implementation success through the proposed four constructs.

Keywords: Content validity, Expert judgment, Total productive maintenance (TPM), Critical Success Factors (CSF).

Resumo

A validação de conteúdo constitui uma etapa crítica e complexa no processo de desenvolvimento de instrumentos de medida comumente utilizados para avaliar construtos complexos em pesquisas sociais e administrativas, pois deve-se garantir que os itens ou variáveis mensuráveis de cada construto sejam representativos. Portanto, o objetivo desta pesquisa foi relatar e discutir de forma prática a validação de conteúdo de um instrumento de medição que avalia o sucesso na implementação da manutenção produtiva total (TPM) com base em cinco construtos: participação e comprometimento da gestão (MPC), educação e formação (ET), envolvimento do pessoal (SI), mudança de cultura organizacional (COC) e sucesso na implementação do TPM (STPM). Para a realização do procedimento de validação utilizou-se o método de julgamento de especialistas e o índice de conteúdo de Lynn (I-CVI), além de revisão de literatura e compilação e formulação dos itens que compõem os construtos, os quais foram validados por meio do julgamento de especialistas, que examinaram as dimensões de relevância, coerência e clareza dos itens. As respostas dos especialistas foram analisadas pelo método do índice de validade de conteúdo de Lynn (I-ICV, S-CVI/ave, S-CVI/UA) para cada item de cada uma das dimensões. Os resultados mostram que os itens são representativos do construto correspondente, o que indica que o instrumento possui validade de conteúdo muito elevada com nível de significância de 5%.

Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Como resultado, é apresentado um instrumento com validade de conteúdo para medir o sucesso da implementação do TPM através dos quatro construtos propostos.

Palavras-chave: validade de conteúdo, julgamento de especialistas, manutenção produtiva total (TPM), fatores críticos de sucesso (FCS).

Reception Date: November 2023 **Acceptance Date:** May 2024

Introduction

Total productive maintenance (TPM), a strategy conceived by Nakajima in 1988, represents a valuable tool to improve the quality of production processes since its focus on continuous improvement has the main objective of maximizing productivity and prolonging the life cycle of industrial equipment (Agustiady and Cudney, 2018; Pascal *et al.*, 2019). Indeed, compared to other maintenance techniques - such as preventive and corrective -, TPM presents several advantages, including the participation and cooperation of all those involved, the development of autonomy and technical skills of the operators, improvement in communication between operators and maintenance technicians, as well as improvement in equipment operational effectiveness, process capabilities, and overall productivity, resulting in minimization of production losses and production costs (Gupta and Vardhan, 2016; Pinto *et al.*, 2020).

Three fundamental indicators are used to evaluate the TPM's effectiveness: the Total Equipment Effectiveness (TEE), the mean time between failures, and the mean time to repair (Prabowo and Adesta, 2019; San, 2021). However, the level of success or effectiveness in implementing TPM varies depending on the company, since it relies on a set of variables that are not directly measurable, known as *latent variables* or *constructs.* In this sense, various latent variables or constructs have been shown to influence the success of TPM implementation, such as Management Participation and Commitment (MPC) (Hooi and Leong, 2017; Mishra *et al.*, 2021; Rathi *et al.*, 2021), Education and Training (ET) (Ahmad *et al.*, 2017; Ngoy and Israel, 2021), Staff Involvement (SI) (Agung Prabowo *et al.*, 2020; Rathi *et al.*, 2021) and Change in Organizational Culture (COC) (Farné, 2020; Mishra *et al.*, 2021).

Therefore, it is essential to address the challenge of identifying and measuring these variables, which cannot always be directly quantified in the industrial environment. Due to the above, the need arises to develop a Measurement Instrument (MI) that ensures content validity, that is, guaranteeing that the instrument contains the relevant and appropriate items

to measure the constructs that are intended to be evaluated. To date, the literature reviewed has not reported any model that relates the constructs MPC, ET, SI, COC, and TPM, nor any instrument that measures the relationship between these constructs.

For this reason, the objective of this research work is to evaluate, through the method of expert judgments, the content validity of the proposed MI to build a multivariate linear regression model in order to establish the causal relationships between success in the implementation of the TPM, as an endogenous variable, and the four constructs MPC, ET, SI, and COC, as exogenous variables. In this regard, it should be noted that content validation plays a crucial role in the process of developing a measurement instrument; since it provides evidence of the validity of the constructs of an MI and lays an effective basis for the construction of forms (Ding and Hershberger, 2022).

Evaluating the content validity of the MI aims to determine whether the proposed questions or items of the MI adequately reflect the content domain that is intended to be measured, taking into account the relevant knowledge, skills, and abilities. The expert judgment method used in this evaluation consists of determining whether there is agreement in the ratings provided by the judges concerning each of the items and the overall set of items, that is, examining whether these agreements are attributable to chance from a statistical approach. To verify these hypotheses, the content validity ratio indices (CVR) (Lawshe, 1975) and the content validity index (CVI) (Lynn, 1986) are used.

In this regard, Almanasreh *et al.* (2019) and Wilson *et al.* (2012) point out the preference for the CVR index to test the hypothesis that the agreements between judges are attributable to chance, due to its simplicity compared to other alternative criteria, its ease of quantification and the availability of a table with the values. critics. However, a monotony problem arises with the critical values for the validity criterion of these critical values for the CVR. Specifically, when the number of expert judges is equal to eight, this critical value breaks the monotony observed in the rest of these values. To solve this problem, Wilson *et al.* (2012) propose to calculate this critical value using equation (1).

$$CVR_{\propto} = \frac{z_{\propto}}{\sqrt{N}} (1)$$

where N represents the total number of judges participating in the evaluation and ∝corresponds to the level of significance with which the agreement test is carried out.

Content validity index (CVI) methods (Lynn, 1986) represent an alternative to the CVR method due to their discriminatory ability (Romero *et al.*, 2023). Almanasreh *et al.*

(2019) and Roebianto *et al.* (2023), among others, chose this index to determine the content validity of the MI in their research. Compared to alternative indices, the CVI has been found to have advantages in ease of calculation, understandability, focus on agreement of relevance rather than the agreement itself, and focus on consensus rather than coherence.

This method evaluates the agreement between the judges for each item of the MI using the individual content validity index (I-CVI), where it is suggested that items with a numerical value of the I-CVI equal to or greater than 0.78, with three or more experts, are considered evidence of good content validity (Polit *et al.*, 2007).

The CVI determines the degree of agreement between the judges at two levels: at the item level (I-CVI) and at the scale level (S-CVI), which measures the agreement between the judges on the entire measurement instrument and is represented by two indices, S-CVI/ave, and S-CVI/UA.

- I-CVI: This is used to evaluate the content validity individually for each item in the instrument. It is determined through the opinion of a panel of experts who rate each item based on its relevance, clarity, and coherence with the construct to which it belongs. Each item receives a rating from the experts, and the I-CVI is measured as the proportion of experts who consider the item to be relevant and appropriate. Typically, an acceptance threshold is established for the I-CVI, and items that do not meet that threshold are revised or eliminated.
- S-CVI/ave (mean scale content validity index): This measure assesses the content validity of the entire MI as a whole. It is determined by averaging the I-CVI of all the items in the instrument, which offers a comprehensive evaluation of the quality of the items in terms of their representativeness and relevance concerning the constructs. A high S-CVI/ave indicates that, on average, the instrument items are relevant and appropriate for measuring the constructs.
- S-CVI/UA (Universal/Cumulative Content Validity Index): This measure also assesses the content validity of the MI as a whole. Unlike S-CVI/ave, S-CVI/UA is calculated taking into account unanimous agreement among experts. That is, an item is considered valid if all experts agree that it is relevant and appropriate, which is useful for identifying items that have a high level of consensus among experts. A high value of the S-CVI/UA indicates that all the items of the instrument are considered essential and appropriate unanimously by the experts.

In the process of calculating content validity, values of 1 and 0 are assigned based on the experts' responses, using a 4-position Likert scale. Furthermore, the value of 1 is assigned to the answers that obtained values of 3 and 4, while the value of 0 is given to those answers that obtained 1 and 2 by the experts. Once the data have been recoded, the indicators are calculated, as shown in Table 1.

Table 1. Formulas for calculating CVI

Indicator	Name	Definition	Formula
I-CVI	Content validity index per item	Proportion of judges who declare the item essential.	$I-CVI=\frac{k}{N}$ k= # of essential items; N= #of judges
S-CVI/ave	Content validity index for the scale, based on the average method	Arithmetic mean of the I-CVI of the items; or the proportion of items classified as essential by each judge (j_i).	$S-CVI/ave=\frac{\sum_{i=1}^{n}(I-VCI_i)}{n}$ $(I-CVI_i)$= I-CVI of item i n= # of items. either $S-CVI/_{ave}=\frac{\sum_{i=1}^{N}j_i}{N}$
S-CVI/UA	Content validity index for the scale, based on the universal agreement method	The proportion of items that are considered relevant.	$S-CVI/UA=\frac{\sum_{i=1}^{n}I_i}{n}$ I_i= 1, if item i is essential Ii = 0, if item i is not essential

Source: Yusoff (2019)

To evaluate the I-CVI, which analyzes each item individually, the proportion of experts who evaluated the item as fundamental is determined, that is, those who assigned a score of 1 in their assessment. For the I-CVI to be considered excellent, it must obtain a value

equal to or greater than 0.78, according to the guidelines established by Polit *et al.* (2007). Regarding the calculation of the S-CVI/bird, this is obtained as the arithmetic mean of the I-CVI of all the items evaluated. To be considered acceptable, the S-CVI/bird must be equal to or greater than 0.90. Finally, in the process of evaluating content validity, it is important to report the cumulative scalar/universal content validity index (S-CVI/UA), an indicator that reflects the proportion of elements that have been evaluated as essential by consensus. among the experts.

Almanasreh *et al.* (2019) state that indices such as Cohen Kappa's K, Fleiss Kappa (multi-rater Kappa), Weighted Kappa, T-index, Gwet's AC1, and others, should be interpreted with caution if used for purposes of assessing content validity, given They are designed and developed to evaluate general agreement among a set of raters, but not for quantifying content validity. These indices can also measure complete inter-rater agreements regardless of the type of agreement, agreement, or disagreement, and adjust the risk of agreement by chance.

Methodology

Materials and methods

The evaluation of the content validity of the MI is carried out in four phases. The first, called “definition”, involves the selection of the constructs and the delimitation of their domains to define the items based on the available literature. The second phase, called “expert judgment,” consists of the selection of specialists who will help evaluate the items and constructs to statistically validate the evaluations carried out. The third phase, called “quantification”, and the fourth phase, “restructuring”, are oriented towards making decisions based on the acquired indicators to determine whether certain items should be modified or eliminated. Finally, in case it is necessary to restructure the MI after considering expert judgment, the content validity of the resulting new MI is evaluated.

Methodology

The methodology of this research was based on a quantitative approach, with an exploratory scope. The research design was observational and transversal inferential type. A sample of six experts was selected using the convenience method, who have the following characteristics: engineering studies, at least 30 years of work experience, three of them with

doctoral level studies in the area of industrial engineering, two with experience in implementing TPM strategy in industry and two currently working in the manufacturing industry. These experts evaluated the instrument items using a 4-point Likert scale to specify the following three characteristics: relevance, clarity, and coherence of the MI items.

Definition

In this phase, the constructs are determined through an exhaustive review of the literature. To this end, we sought to establish a solid theoretical basis to operationally define the instrument that will measure the latent variable or construct. Likewise, various search engines such as Research Gate, Science direct, Emerald, Google Scholar, IEEE, among others, were used with the objective of identifying articles related to the implementation of the TPM philosophy, the critical success factors, and the structural models of TPM (in this case, in the period from 2017 to 2023). Subsequently, the latent variables were identified to define the constructs and develop the corresponding items. In total, five constructs were established: management participation and commitment (MPC), education and training (ET), staff involvement (SI), organizational culture change (CC), and success in implementing TPM (STPM).

Analysis

The data obtained in the expert judgment method were analyzed using the content validity index (CVI), proposed by Lynn (1986) and supported by Yusoff (2019). This method establishes ranges according to the number of experts and evaluates the agreement between the judges concerning each of the items through the individual content validity index (I-CVI). Additionally, the scale quality of the items is measured using the average scalar content validity index (S-CVI/ave). The cumulative universal content validity index (S-CVI/UA) is also represented, which indicates the percentage of items that were declared essential by the unanimous decision of the experts. These parameters were used following the recommendations of Almanasreh *et al.* (2019) and Saputra *et al.* (2023).

Features to Evaluate

The categories evaluated by the experts for each item belonging to the measurement instrument were the following:

- Relevance: Refers to the importance of the item and determines whether it is necessary to eliminate it from the MI.
- Coherence: Evaluates the correspondence of the item with the dimension to which it belongs.
- Clarity: Measures how appropriate the wording is to describe the item.

Criteria of Acceptance

It is assumed that there is agreement between the judges: for each item, if the value of the I-CV1 indicator is greater than or equal to 0.78 (Polit *et al.*, 2007) ; for the MI, if the value of the S-CV1/ave indicator is greater than or equal to 0.90 (Naye, *et al.*, 2022; Polit *et al.*, 2007) .

MI Evaluation

The categories were evaluated through the 4-point Likert scale in each of them, where ratings 1 and 2 are considered to indicate low importance, while ratings 3 and 4 indicate that the items are essential. Below, the descriptions of the weights are established according to the following criteria:

Relevance

- 1. Not important: The item is dispensable and does not cause a significant impact on the dimension.
- 2. Unimportant: The item has some importance, but could be measured by another element.
- 3. Important: The item is considered relevant.
- 4. Very important: The item is highly relevant and it is recommended to include it.

Coherence

- 1. Not important: The item lacks coherence with the dimension evaluated.
- 2. Unimportant: The item is partially related to the dimension.
- 3. Important: The item shows an intermediate connection with the dimension.
- 4. Very important: The item is closely linked to the dimension being evaluated.

Clarity

- 1. Not important: The item lacks clarity and is not understandable.

- 2. Unimportant: The item requires quite a few modifications to improve its understanding.
- 3. Important: The item requires some modifications to improve its clarity.
- 4. Very important: The item is clear and appropriate in its wording.

MI Restructuring

After evaluating the agreement between the experts, an analysis was carried out to determine if it is necessary to adjust or eliminate the items that are not considered appropriate. If modifications are required, the instrument is subject to a review again by the experts, who may be the same ones who participated in the first evaluation or a new group of experts, following the approach suggested by Almanasreh. *ET al.* (2019).

Results

Definition of Constructs

Five factors or constructs are identified that influence the result obtained in the TPM implementation process: management participation and commitment (MPC), education and training (EC), employee involvement (SI), organizational culture change (COC), and success in implementing the TPM (STPM). For each construct, various items are developed to be evaluated, resulting in a measurement instrument with 48 items corresponding to the different constructs: MPC has 15 items, ET with 10 items, SI with 8 items, COC with 5 items, and STPM with 10 items.

The MPC construct constitutes the exogenous variable, defined as the main critical support to achieve success in the implementation of the TPM. This includes the commitment and involvement of management, which translates into support to contribute to the achievement of objectives, manage implementation in an environment of cooperation and trust, and provide workers with the necessary tools, which is achieved through communication and leadership, which convey the understanding of approach, supervision, the ability to change and the motivation necessary for workers (Agung Prabowo *et al.*, 2020; Hooi and Leong, 2017).

The following constructs are also defined as follows:

- ET: Ability to develop adequate knowledge of TPM in workers through specialized training according to positions, which allows them to acquire skills necessary for

success in the initial stage of implementing the TPM philosophy (Mishra *et al.*, 2021; Ngoy and Israel, 2021).

- SI: Collaboration of staff at all levels, from management to operators, to engage in decision-making and work as a team (Pascal *et al.*, 2019; Rathi *et al.*, 2021; Zennaro *et al.*, 2019).
- COC: Willingness to change from traditional practices to new practices in daily activity, considering the change in organizational culture (Badiea *et al.*, 2023; Rathi *et al.*, 2021).
- STPM: Improvement in efficiency, cost reduction, quality improvement, staff participation, autonomy in maintenance, job security, and the ability to maintain and improve over time (San, 2021; Singh *et al.*, 2023; Sukma *et al.*, 2022).

Expert judgment and quantification

A group of six experts was formed who evaluated the 48 items of the MI using a 4-point Likert scale to evaluate the relevance, clarity and coherence of each item. Likewise, the I-CVI, S-CVI/Ave and S-CVI/UA were calculated following the procedure established by Polit *et al.* (2007). In the first round of evaluation, the experts identified 17 items as insufficient, of which 2 were eliminated due to their lack of relevance, leaving the remaining 15 items that required restructuring. This led to a second round of the expert judgment method.

Once the 15 items classified as insufficient were redefined, they were integrated into the corresponding position in the MI to be subjected to a second round of evaluation with the same 6 experts who participated in the first round. When again collecting the ratings assigned by the experts for these 15 items, it was found that 9 of them obtained a favorable agreement, so 6 items were eliminated. This resulted in an MI with content validity (table 2), since all the I-CVI were above the value of 0.78, with values ranging between .833 and 1. Therefore, it was concluded that there is agreement between the experts for each of the items.

Regarding the S-CVI/ave, values greater than .90 were obtained in each of the categories: relevance with 0.988, clarity with 0.9841 and coherence with 0.9801. The values of the S-CVI/UA indicator for the categories were 0.929 in relevance, 0.9047 in clarity and 0.8809 in coherence. Finally, the MI demonstrated content validity, with 5 constructs developed in 42 items (Table 3), distributed as follows: MPC with 14 items, ET with 9 items, SI with 8 items, COC with 4 items and STPM with 7 items.

Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Table 2. Evaluations of the characteristics *relevance*, *clarity* and *coherence* of the measurement instrument

	Relevance			Clarity			Coherence		
Item	I-CVI	$\frac{I-CVI}{ave}$	$\frac{I-CVI}{UA}$	I-CVI	$\frac{I-CVI}{ave}$	$\frac{I-CVI}{UA}$	I-CVI	$\frac{I-CVI}{ave}$	$\frac{I-CVI}{UA}$
1	1	0.988	0.929	0.833	0.9841	0.9047	0.8333	0.9801	0.8809
2	1			1			1		
3	1			1			1		
4	1			1			1		
5	1			1			1		
6	1			1			1		
7	1			1			1		
8	1			1			0.833		
9	1			1			1		
10	1			1			1		
eleven	0.833			1			1		
12	1			1			1		
13	1			0.833			1		
14	1			1			1		
fifteen	1			1			1		
16	1			1			1		
17	1			1			1		
18	1			1			1		
19	1			1			1		
twenty	1			1			1		

twenty-one	1			1			1		
22	1			1			1		
23	1			1			1		
24	1			1			1		
25	1			1			0.8333		
26	1			1			1		
27	0.8333			0.8333			0.8333		
28	1			1			1		
29	1			1			1		
30	1			1			0.8333		
31	1			1			1		
32	1			1			1		
33	1			1			1		
3. 4	1			1			1		
35	1			1			1		
36	1			1			1		
37	1			1			1		
38	1			1			1		
39	1			1			1		
40	1			1			1		
41	1			0.8333			1		
42	0.8333			1			1		

Source: self-made

Measuring Instrument

Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

The MI that was obtained after the evolution carried out by the experts is presented in Table 3, where the items corresponding to each of the constructs or variables MPC, ET, SI, and BCC, are shown

Table 3. MI format applied in the expert judgment

Item	Latent variable: management participation and commitment	Feature to evaluate												Observations
		Coherence				Clarity				Relevance				
		1	2	3	4	1	2	3	4	1	2	3	4	
1	MPC1. Responsibilities within our maintenance program are clearly defined in all sections of the plant.													
2	MPC2. The formulation of the company's mission, strategies, and policies reflect the commitment of senior management to the maintenance of the team.													
3	MPC 3. Management clearly understands the TPM approach.													
4	MPC 4. The organization's goals support the development of the TPM program.													
5	MPC 5. Management leadership is perceived in the execution of TPM programs.													
6	MPC 6. Management supports quality objectives with the implementation of TPM.													
7	MPC 7. There is management support in the maintenance program.													
8	MPC 8. Management motivates teamwork.													
9	MPC 9. Management is effective in executing TPM.													
10	MPC 10. The organization's managers provide an environment of cooperation and trust for the implementation of TPM.													

eleven	MPC 11. Senior management assigns an efficient mentor/supervisor for TPM implementation.													
12	MPC 12. Executive management provides the essential tools to carry out the implementation of the TPM.													
13	MPC 13. The organization can improve employees' skills at work.													
14	MPC 14. There are incentives that motivate employees.													
Item	Latent variable: education and training	Feature to evaluate												Observations
		Coherence				Clarity				Relevance				
		1	2	3	4	1	2	3	4	1	2	3	4	
fifteen	ET1. The right training program helps to learn about the benefits of TPM.													
16	ET2. Employees acquire the appropriate skills to implement TPM after training.													
17	ET3. Employees are aware of new technologies due to proper training.													
18	ET4. Before the implementation of the TPM, personalized training is offered according to the different positions with the objective of acquiring the knowledge and skills necessary for effective compliance.													
19	ET5. Management masters the TPM methodology.													
twenty	ET6. Training prior to TPM implementation shows why and why of such training.													
twenty-one	ET7. Training prior to the implementation of TPM helps initiate a change in cultural mentality among workers.													
22	ET8. Training prior to the implementation of the TPM helps													

	to improve the work environment.													
23	ET9. Training prior to TPM implementation encourages greater employee interest in equipment efficiency.													
Item	Latent variable: staff involvement	Feature to evaluate												
		Coherence				Clarity				Relevance				Observations
		1	2	3	4	1	2	3	4	1	2	3	4	
24	SI1. You work in teams to solve production problems and encourage employee participation.													
25	SI2. All positions from management to operations are involved in the activities to achieve the effective implementation of TPM.													
26	SI3. Employees participate in decision-making.													
27	SI4. Operators are responsible for maintaining their machines.													
28	SI5. Operators are responsible for inspecting their own work.													
29	SI6. There is a program that ensures the regular evaluation and implementation of suggestions submitted by employees.													
30	SI7. There is a program that guarantees that the administration communicates why the suggestions were or were not implemented.													
31	SI8. Periodic meetings are assigned to maintain communication at different levels.													
Item	Latent variable: organizational culture change	Feature to evaluate												
		Coherence				Clarity				Relevance				Observations
		1	2	3	4	1	2	3	4	1	2	3	4	

32	COC1. I believe that the implementation of TPM is clearly effective in improving maintenance practices in the industry.													
33	COC2. The cultural change of workers is important in the success of TPM implementation.													
3. 4	COC3. The success of TPM implementation depends largely on the organizational culture of each company.													
35	COC4. The implementation of TPM includes more improvement tools than other programs.													
	Items per dimension or construct to evaluate	Feature to evaluate												
	Success in implementing TPM How much do I agree that…	Coherence				Clarity				Relevance				Observations
		1	2	3	4	1	2	3	4	1	2	3	4	
36	STPM1. TPM develops competitive job skills													
37	STPM2. TPM improves the quality of the final product.													
38	STPM3. The number of rejections and re-works are reduced with the implementation of TPM.													
39	STPM4. TPM implementation reduces costs.													
40	STPM5. The implementation of TPM increases the operational effectiveness of plant equipment.													
41	STPM6. The implementation of TPM increases continuous improvement.													
42	STPM7. The implementation of TPM reduces the number of accidents in the work area.													

Source: self-made

Discussion

The measurement instrument (Table 3) demonstrates content validity in the three characteristics evaluated: relevance, clarity, and coherence. This is evident in the analysis of the data obtained from the experts' evaluation, whose numerical results exceed the critical values established for the indicators I-CVI (≥0.78), S-CVI/ave (≥0.90), and S-CVI/ UA (≥0.90) (Polit *et al.*, 2007). The first round of evaluation did not provide satisfactory results, which motivated a second round with the same panel of experts to achieve the correct indicators.

Conclusions

The measurement instrument presented in this research study has demonstrated content validity, which means that the items assigned to each construct represent it adequately and completely. These items are highly relevant, clear in their formulation, and coherent in their relationship with the concepts they represent within the scope of the definition of each construct. Therefore, this instrument is suitable and valid for the collection of data necessary to carry out statistical analyzes aimed at evaluating the statistical validity of the hypotheses related to the five constructs considered. In this regard, it is worth remembering that content validation is based on the use of reliable criteria, such as the I-CVI, S-CVI/ave, and S-CVI/UA indicators, which are solid criteria for estimating content validity.

Future lines of research

The modified Kappa indices and Kendall's concordance test, proposed by Polit *et al.* (2007) evaluate the agreement between the judges for the ratings assigned to the MI, but they do not determine this agreement for each item individually. Therefore, it is not possible to determine whether the discrepancy observed in each item is due to chance (Almanasreh *et al.*, 2019). Despite their inability to discriminate the effects of randomness in assessing agreement in expert judgment, these methods are still applied to validate the content of MIs (Carlton *et al.*, 2022; Feng *et al.*, Reick, 2022). That is, from a statistical point of view, the results obtained when evaluating the content validity of an MI with these methods are questionable.

On the other hand, the CVR and CVI indices are used to determine whether the judges' agreement for the MI and for each item is attributable to chance (Alqahtani *et al.*, 2023). According to theory, these last two methods are superior to the first two. Given these two

alternatives available to evaluate the content validity of the MI, it is recommended to carry out a simulation study to compare the effectiveness of these four indicators in the evaluation of agreement for the MI and for the items.

Thanks

Thanks to the SEP-SES for its support to Paola Fernanda Castillo Salcido, current scholarship recipient, through the National Short Stay Support Program for Doctoral Studies.

Rafael García Martínez received financial support for the research, authorship, and/or publication of this article from the National Council of Humanities, Science and Technology (CONAHCYT) through the Postdoctoral Stays Program in Mexico 22 (1).

References

Agung Prabowo, H. A., Hilmy, I. and Triblas Adesta, E. Y. (2020). Total productive maintenance implementation's barriers and enablers in Indonesian manufacturing companies. *2020 Advances in Science and Engineering Technology International Conferences, ASET 2020*, 1-6. https://doi.org/10.1109/ASET48392.2020.9118224

Agustiady, T. K. and Cudney, E. A. (2018). Total productive maintenance. *Total Quality Management and Business Excellence*, *0*(0), 1–8. https://doi.org/10.1080/14783363.2018.1438843

Ahmad, N., Hossen, J. and Ali, S. M. (2017). Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case. *International Journal of Advanced Manufacturing Technology*, *94*(1–4), 239–256. https://doi.org/10.1007/s00170-017-0783-2

Almanasreh, E., Moles, R. and Chen, T. F. (2019). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *15*(2), 214–221. https://doi.org/10.1016/j.sapharm.2018.03.066

Alqahtani, T. M., Yusop, F. D. and Halili, S. H. (2023). Content validity of the Constructivist Learning in Higher Education Settings (CLHES) scale in the context of the flipped classroom in higher education. *Humanities and Social Sciences Communications*, *10*(1), 1-12. https://doi.org/10.1057/s41599-023-01754-3

Badiea, A. M., Wael, B. A. and Adel, A. A. (2023). Implementing Total Productive Maintenance in Yemeni Company for Industry and Commerce (YCIC): Case Study. *European Journal of Applied Sciences*, *11*(2). https://doi.org/10.14738/aivp.112.12966

Carlton, J., Powell, P. A. and Project HERCULES Carer Group. (2022). Measuring carer quality of life in Duchenne muscular dystrophy: a systematic review of the reliability and validity of self-report instruments using COSMIN. *Health and Quality of Life Outcomes*, *20*(1), 57. https://doi.org/10.1186/s12955-022-01964-4

Ding, C. S. & Hershberger, S. L. (2022). Assessing Content Validity and Content Equivalence Using Structural Equation Modeling, *Structural Equation Modeling: A Multidisciplinary Journal*, 9(2), 283-297. https//doi.org/10.1207/S15328007SEM0902_7.

Farné, S. (2020). Application and Results of the TPM Methodology in a Factory for the Production of Agricultural and Earth-Moving Machines. *Asian Journal of Basic Science & Research*, *2*(4), 1–11. https://doi.org/DOI: 10.38177/AJBSR.2020.2401

Feng, D., Huang, S., Lang, X., Liu, Y. and Zhang, K. (2022). Developing an exercise attitudes and behavior intentions questionnaire for survivors of aortic dissection: an exploratory factor analysis. *Reviews in Cardiovascular Medicine*, *23*(10), 337. https://doi.org/10.31083/j.rcm2310337

Gupta, P. and Vardhan, S. (2016). Optimizing TEE, productivity and production cost for improving sales volume in an automobile industry through TPM: A case study. *International Journal of Production Research*, *54*. 2976-2988. https://doi.org/10.1080/00207543.2016.1145817

Hooi, L. W. and Leong, T. Y. (2017). Total Productive Maintenance and Manufacturing Performance Improvement. *Journal of Quality in Maintenance Engineering*, *23*(1). 2-21. http://dx.doi.org/10.1108/JQME-07-2015-0033

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, *28*(4), 563-575.

Lynn, M. R. (1986). Determination and Quantification Of Content Validity. *Nursing Research 35*(6), 382-386. https://doi.org/10.1097/00006199-198611000-00017

Ma, H., Hu, Z., Wang, Z., Ma, Y., Zhai, H. and Li, J. (2023). Development and Validation of a New Comprehensive Assessment Scale of HIV-Related Psychological Distress

in China: A Methodological Study. *Journal of the Association of Nurses in AIDS Care*, *34*(3), 292-306. https://doi.org/10.1097/JNC.0000000000000402

Mishra, R. P., Gupta, G. and Sharma, A. (2021). Development of a Model for Total Productive Maintenance Barriers to Enhance the Life Cycle of Productive Equipment. *Procedia CIRP*, *98*, 241–246. https://doi.org/10.1016/j.procir.2021.01.037

Nakajima, S. (1988). *Introduction to Total Productive Maintenance (TPM)*. Cambridge, Massachusetts Productivity Press.

Naye, F., Décary, S. and Tousignant-Laflamme, Y. (2022). Development and content validity of a rating scale for the pain and disability drivers management model. *Archives of Physiotherapy*, *12*(1), 1-11. https://doi.org/10.1186/s40945-022-00137-2

Ngoy, K. R. and Israel, K. (2021). The Strategy of Successful Total Productive Maintenance (TPM): Implementation and Benefits of TPM (Literature Review). *Ijirmps*, *9*(6), 43–52. www.ijirmps.org

Pascal, V., Toufik, A., Manuel, A., Florent, D. and Frédéric, K. (2019). Improvement indicators for Total Productive Maintenance policy. *Control Engineering Practice*, *82*(September 2018), 86–96. https://doi.org/10.1016/j.conengprac.2018.09.019

Pinto, G., Silva, F. J. G., Baptista, A., Fernandes, N. O., Casais, R. and Carvalho, C. (2020). TPM implementation and maintenance strategic plan - A case study. *Procedia Manufacturing*, *51*(2020), 1423–1430. https://doi.org/10.1016/j.promfg.2020.10.198

Polit, D. F., Beck, C. T. and Owen, S. V. (2007). Is the CVI an Acceptable Indicator of Content Validity? Appraisal and Recommendations. *Res Nurs Health*, *30*(4), 459-67. https://doi.org/10.1002/nur.

Prabowo, H. A., & Adesta, E. Y. T. (2019). A study of total productive maintenance (TPM) and

lean manufacturing tools and their impact on manufacturing

performance. *International Journal of Recent Technology and Engineering*, *7*(6), 39–43.

Rathi, R., Singh, M., Sabique, M., Al Amin, M., Saha, S. and Hari Krishnaa, M. (2021). Identification of total productive maintenance barriers in Indian manufacturing industries. *Materials Today: Proceedings*, 50, 736-742. https://doi.org/10.1016/j.matpr.2021.05.222

Reick, S., Burckhardt, M., Palm, R. and Kottner, J. (2023). Measurement instruments to evaluate diaper dermatitis in children: Systematic review of measurement properties. *Nursing Open 10*(9). https://doi.org/10.1002/nop2.1863

Roebianto, A.., Savitri, S. I., Aulia, I.., Suciyana, A. and Mubarokah, L. (2023). Content validity: Definition and procedure of content validation in psychological research. *TPM*, *30*(1), 5-18. http://dx.doi.org/10.4473/TPM30.1.1

Romero, M., Díaz Costa, E. and Faouzi Nadim, T. (2023). A Review of Lawshe's Method for Calculating Content Validity in the Social Sciences. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1271335

San, S. (2021). A Systematic Literature Review of Total Productive Maintenance On Industries. *Performa: Media Ilmiah Teknik Industri*, *20*(2), 97. https://doi.org/10.20961/performa.20.2.50087

Saputra, A., Kusumawardhani, A. A. A. A., Elvira, S. D. and Wiguna, T. (2022). An item development, content validity, and feasibility study towards the Indonesian recovery scale for patients with schizophrenia. *Heliyon*, *8*(11). https://doi.org/10.1016/j.heliyon.2022.e11826

Singh, S., Kumar, M. andamp; Kumar, S. (2023). Implementation of Total Productive Maintenance to Improve Productivity of Rolling Mill. *Indian Journal of Engineering & Materials Sciences*, *30*(december), 882–890. https://doi.org/10.56042/ijems.v30i6.3158

Sukma, D. I., Prabowo, H. A., Setiawan, I., Kurnia, H. andamp; Fahturizal, I. M. (2022). Implementation of Total Productive Maintenance to Improve Overall Equipment Effectiveness of Linear Accelerator Synergy Platform Cancer Therapy. *International Journal of Engineering, Transactions A Basics*, *35*(7), 1246–1256. https://doi.org/10.5829/ije.2022.35.07a.04

Wilson, F. R., Wei, P. and Donald, A. S. (2012). Recalculation of the Critical Values for Lawshe's Content Validity Ratio. *Measurement and Evaluation in Counseling and Development*, *45*(3). https://doi.org/10.1177/0748175612440286

Yusoff, M. (2019). ABC of Content Validation and Content Validity Index Calculation. *Education in Medicine Journal*, *11*(2), 49–54. https://doi.org/10.21315/eimj2019.11.2.6

Zennaro, I., Battini, D., Sgarbossa, F. andamp; Persona, A. (2019). *TPM Implementation in automated flow line manufacturing systems : criticalities and key factors to support a*

faster implementation. Conference: Summer school Francesco Turco.

Contributing role	Author(s)
Conceptualization	Paola Fernanda Castillo Salcido
Methodology	Paola Fernanda Castillo Salcido
Software	Rafael García Martínez
Validation	Paola Fernanda Castillo Salcido, “same” Rafael García Martínez
Formal analysis	Paola Fernanda Castillo Salcido
Investigation	"Principal" Paola Fernanda Castillo Salcido, "equal" Rafael García Martínez, "who supports" Jesús Andrés Hernández Gómez, "who supports" Eduardo Rafael Poblano Ojinaga, "who supports" Salvador A. Noriega Morales.
Resources	Paola Fernanda Castillo Salcido
Data curation	Paola Fernanda Castillo Salcido
Writing - Preparation of the original draft	Paola Fernanda Castillo Salcido
Writing - Review and editing	«main» Paola Fernanda Castillo Salcido, «equal» Salvador A. Noriega Morales.
Display	«main» Paola Fernanda Castillo Salcido, "same" Rafael García Martínez, "same" Jesús Andrés Hernández Gómez, "same" Eduardo Rafael Poblano Ojinaga, "same" Salvador A. Noriega Morales.
Supervision	Paola Fernanda Castillo Salcido
Project management	"same" Paola Fernanda Castillo Salcido, "same" Rafael García Martínez, "same" Jesús Andrés Hernández Gómez,
Fund acquisition	Paola Fernanda Castillo Salcido