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Difficulties observed when implementing Total Productive Maintenance (TPM): empirical evidences from the manufacturing sector

Dificuldades observadas na implementação da Manutenção Produtiva Total (TPM): evidências empíricas do setor manufatureiro

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Abstract: This article analyses the difficulties observed in adopting the Total Productive Maintenance (TPM) program in production systems. The research strategies used for this purpose consisted of a literature review, a panel of experts and a survey with professionals working in manufacturing companies. Altogether, 69 market professionals took part in the survey and the collected data was analyzed through the PLS-SEM technique. Results indicate that there is a causal relationship between difficulties associated with the planning phase of a TPM program and issues associated with its implementation. This is an original research and the results are valuable to business professionals desiring to properly implement TPM, as well for researchers interested in the mechanics of total productive maintenance system's adoption.

Keywords: Total Productive Maintenance; TPM; Difficulties; Barriers.

Resumo: Este artigo analisa as dificuldades observadas na adoção do programa Manutenção Produtiva Total (TPM) em sistemas de produção. As estratégias de pesquisa utilizadas para esse fim consistiram em uma revisão da literatura, um painel de especialistas e uma pesquisa com profissionais que trabalham em empresas de manufatura. Ao todo, 69 profissionais do mercado participaram da pesquisa e os dados coletados foram analisados pela técnica PLS-SEM. Os resultados indicam que existe uma relação causal entre as dificuldades associadas à fase de planejamento de um programa de TPM e questões associadas à sua implementação. Esta é uma

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pesquisa original e os resultados são valiosos para profissionais de negócios desejando implementar adequadamente o TPM, bem como para pesquisadores interessados nos mecanismos da adoção do sistema de manutenção produtiva total.

Palavras-chave: Manutenção Produtiva Total; TPM; Dificuldades; Barreiras.

1 Introduction

Due to high competitiveness and continuous search for profitability, organizations have been facing challenges worldwide and are under pressure to become more flexible and efficient, aiming towards a better quality of products in the desired deadlines, at low cost and fully meeting the growing customer's requirements (da Costa et al., 2015; McKone et al., 2001; Wickramasinghe & Perera, 2016).

In this scenario, maintenance activities have had their role changed and started to be evaluated as strategic tools (Bartz et al., 2014), among them the TPM (Total Productive Maintenance). TPM is a management approach born in Japan, focused on improving productivity and the quality of manufactured goods, minimising losses and reducing costs (Poduval et al., 2013; Sahoo, 2018). Originally a maintenance tool, it evolved over the years into a management tool, seeking to involve professionals from all departments and hierarchical levels to ensure effective operations (Chan et al., 2005; Jain et al., 2014).

Due to TPM's complexity, many organizations around the world face difficulties in successfully implementing it (Kumar Sharma & Gopal Sharma, 2014; McKone et al., 2001; Wickramasinghe & Perera, 2016). The scientific literature concerning difficulties and barriers in implementing a TPM program is limited and only a few studies allow broader conclusions, even though they mostly of qualitative nature restricted to a region or country. In particular, there is no studies dedicated to understanding how the planning phase of a TPM program affects its implementation in the manufacturing sector. Therefore, there is an interesting research gap: to better understand the difficulties associated with the TPM program planning and implementation via structural equations modelling, although our results are mainly of exploratory nature. With the advent of Industry 4.0 and the emergence of novel advanced analytic approaches (Schwab, 2016), predictive maintenance and TPM as a whole are becoming more and more important in the manufacturing sector (Lee et al., 2015), thus it is an important research topic today.

In this context, the main objective of this paper is to understand how the difficulties observed when adopting the TPM program in productive systems are structured. Four specific objectives are defined: 1) gather in the literature the main difficulties associated with the adoption of the TPM program in production systems; 2) bring together an experts panel in order to allocate the difficulties mentioned in some constructs related to the planning stage and the implantation phase; 3) conduct a survey with industry professionals who adopted the TPM program; and 4) test the hypothesis that the difficulties associated with the implementation phase are directly related to the planning phase. The term "TPM in production systems" stands out because it can be applied to office areas, which is not the focus of this work.

In addition to this introduction, this article consists of 4 additional sections. Section 2 presents the background, explaining the basic concepts of TPM and the main difficulties associated to its adoption. Section 3 introduces the methodological procedures used by the authors. Section 4 presents and discusses the results from the experts' panel and from the structural equations modelling. Finally, Section 5 outlines the main conclusions and future research directions.

2 Theoretical background

TPM originated from two correlated areas: maintenance and reliability (Mckone & Weiss, 1998). It first arose in Japan within the Nippon Denso company, part of the Toyota group, with the purpose to maintain the equipment regularity (Bartz et al., 2012; Rodrigues & Hatakeyama, 2006). According to Nakajima (1988), the history of Japan has been marked by three phases of maintenance and over the last 100 years: the corrective, the preventive and the predictive maintenance, which later evolved and resulted in the TPM Program (da Costa et al., 2015).

One of the TPM's objective is to maximize equipment's effectiveness throughout its lifecycle and to keep it in optimum conditions to prevent unexpected failures, avoid speed losses, downtime and quality defects (Agustiady & Cudney, 2018; Carannante et al., 1996; da Silva et al., 2017; Jain et al., 2014; Singh et al., 2016). The three fundamental goals of TPM are: zero defects, zero accidents, and zero break downs (Nakajima, 1988; Noon et al., 2000; Willmott, 1994). Labib (1999) sets TPM's primary goal as the ability to enable a critical maintenance and an approximation between polyvalent operators and production employees in joint works. TPM is also characterized by promoting and exercising synergy among all organizational functions, emphasizing production and maintenance to ensure continuous improvements of product quality, operational efficiency, capacity warranty and security (Aspinwall & Elgharib, 2013; Jain et al., 2014; Kumar Sharma & Gopal Sharma, 2014; Park & Han, 2001).

Pascal et al. (2019) and Ahuja & Khamba (2008a) affirm that TPM is a continuous improvement methodology that enhances confidence in equipment and in management efficiency by improving motivation and satisfaction of the people involved at all working levels, integrating production, maintenance and engineering activities. It should not be considered only as a specific maintenance policy, but rather as a culture, a philosophy and a change of attitude towards maintenance (Ahuja & Khamba, 2008b).

The basic practices of TPM are known as pillars and the complete implementation goes through eight fundamental pillars: 1) autonomous maintenance; 2) focused maintenance; 3) planned maintenance; 4) quality and maintenance; 5) education and training; 6) administrative TPM; 7) development and management; 8) safety, health and environment (Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Bartz et al., 2014; Jain et al., 2015; Jain et al., 2014; Kumar Sharma & Gopal Sharma, 2014; Rodrigues & Hatakeyama, 2006; Singh Amin et al., 2013).

Business organizations around the world continue to experience difficulties in successfully implementing TPM (Ahuja & Khamba, 2008b). Panneerselvam (2012 *apud* (Jain et al., 2014)) and Horner (1996 *apud* (Ahuja & Khamba, 2008b)) agree that the TPM implantation involves a long-term planning, since it requires time to change the attitude of high management and its employees. As the TPM implementation requires significant changes in the organization's culture, it also requires a well-founded implementation plan (Aspinwall & Elgharib, 2013).

Aiming to understand the main difficulties when adopting TPM, a literature review was conducted, leading us to twelve main difficulties presented in Table 1. These difficulties were used as basis to structure the questionnaire.

Table 1. Difficulties of TPM implantation found in the literature.

n	Description	References
1	Difficulty in selling the project to the company's board, i.e. justifying that improvements in the production indicators will arise from the TPM implementation.	(Ahuja & Khamba, 2008a; Baglee & Knowles, 2010; Bartz et al., 2012; Estanqueiro & Lima, 2006; Graisa & Al-Habaibeh, 2011; Singh et al., 2016; Torres, 2014)
2	Collaborators' resistance related to cultural changes provided by the implementation of TPM.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Attri, Grover, Dev, & Kumar, 2013; Bamber, Sharp, & Hides, 1999; Bartz et al., 2012; Carrijo, 2008; Cigolini & Turco, 1997; Cooke, 2000; da Costa et al., 2015; Estanqueiro & Lima, 2006; Gupta, Vardhan, & Al Haque, 2015; Lawrence, 1999; Milara Guedes, 2009; Poduval, Pramod, & Jagathy Raj, 2015; Rodrigues & Hatakeyama, 2006)
3	Problems in deploying pilot studies as an embryo for subsequent dissemination of the program throughout the company.	(Aspinwall & Elgharib, 2013; Attri, Grover, & Dev, 2014; Attri et al., 2013; Poduval et al., 2015; Poduval et al., 2013; Singh et al., 2016)
4	Low priority in allocating financial resources by the company to TPM implementation.	(Aspinwall & Elgharib, 2013; Attri et al., 2013; Baglee & Knowles, 2010; Cooke, 2000; P.S. Poduval et al., 2015; Poduval et al., 2013; Rodrigues & Hatakeyama, 2006)
5	Collaborators' deficit understanding the philosophy, principles and tools that compose the TPM program.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Attri et al., 2014, 2013; Baglee & Knowles, 2010; Bamber et al., 1999; Carrijo, 2008; da Costa et al., 2015; Gupta et al., 2015; Lawrence, 1999; Milara Guedes, 2009; P.S. Poduval et al., 2015; Rodrigues & Hatakeyama, 2006; Singh et al., 2016)
6	Poor planning about collaborators training needs.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Attri et al., 2014, 2013; Baglee & Knowles, 2010; Bamber et al., 1999; da Costa et al., 2015; Graisa & Al-Habaibeh, 2011; Gupta et al., 2015; Poduval et al., 2015; Singh et al., 2016)
7	Lack of support by senior management to raise awareness on the importance of the program.	(Ahuja & Khamba, 2008b; Ahuja & Kumar, 2009; Aspinwall & Elgharib, 2013; Attri et al., 2014, 2013; Bamber et al., 1999; Carrijo, 2008; Cooke, 2000; Gupta et al., 2015; Kelly, 2006; P.S. Poduval et al., 2015; Poduval et al., 2013; Singh et al., 2016)
8	Deficient communication and low synergy among areas involved in the TPM implantation.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Attri et al., 2014, 2013; Baglee & Knowles, 2010; Cooke, 2000; Estanqueiro & Lima, 2006; Rodrigues & Hatakeyama, 2006; Singh et al., 2016)
9	Difficulty in allocating greater responsibility and autonomy to collaborators.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Cooke, 2000; Lawrence, 1999; Milara Guedes, 2009; Singh et al., 2016)
10	Poor planning related to targets and goals to be achieved by deploying the TPM program.	(Ahuja & Khamba, 2008b; Aspinwall & Elgharib, 2013; Attri et al., 2014; Bamber et al., 1999; Estanqueiro & Lima, 2006; Graisa & Al-Habaibeh, 2011; Gupta et al., 2015; Milara Guedes, 2009; Poduval et al., 2015; Singh et al., 2016)
11	Non-compliance with all initially planned sequential stages.	(Aspinwall & Elgharib, 2013; Attri et al., 2014; Bamber et al., 1999; Estanqueiro & Lima, 2006; Milara Guedes, 2009; Rodrigues & Hatakeyama, 2006; Singh et al., 2016; Torres, 2014)
12	Lack of a common language to be used by all employees in the implementation of the program's activities.	(Attri et al., 2014; da Costa et al., 2015; Graisa & Al-Habaibeh, 2011; Poduval et al., 2015; Poduval et al., 2013; Torres, 2014)

Source: (see table).

3 Methodological procedures

This paper follows a mixed-research approach. According to Gray (2012), mixed research considers qualitative and quantitative aspects. To better understand the TPM as a business phenomenon, a qualitative approach is first employed. Next, we employed a quantitative method, using a numerical scale to quantify the perception level of the difficulties and to perform statistical analyses, as a pre-confirmatory study. This is an exploratory research, with an applied nature. Although TPM programs existed for many decades, there are few plausible conclusions in the literature that could be generalized to this thematic.

More precisely, this study was based on literature review, expert panel and survey. The literature review surveyed the main difficulties associated with the adoption of TPM programs; the expert panel enabled the segregation of these difficulties in thematic groups and, lastly, the survey led to the perception of professionals relating to these difficulties. Finally, the data collection was done through a questionnaire and its analysis was conducted via structural equation modelling (SEM).

The methodological procedures followed these steps: systematic literature review, expert panel, questionnaire structuring and survey application, data analysis via PLS-SEM, discussions and conclusions. Each step will be presented in the sequence.

The bibliographical review was conducted through scientific articles found in the following databases: Taylor & Francis Online, Emerald, Scopus, Elsevier, Omnia Science, Scielo, Capes, Springer, Web of Science, Science Direct and Wiley. The search used the term “Total Productive Maintenance” and in general, 159 articles were found. The previous term combined with the words “Barriers” and “Difficulties” resulted in 25 articles, used to compose Table 1. It is worth highlighting that a total of 47 articles were used in this article, mainly to structure the conceptual base on TPM.

The next step was the experts’ panel, also known as a Nominal Group Technique (NGT). According to Campos et al. (2010), this is a discussion method in small groups of experts in the subject that allows selecting, making trials and contributing to the creativity of suggestions and debates. The experts’ panel was used to segregate the difficulties raised in the literature in two thematic groups which were used as the basis of the survey. This approach in preliminary stages is suggested by Pinheiro et al. (2013). In this phase, there were 10 experts, 5 of which were doctors in Industrial Engineering and 5 were industry professionals and consultants. Table 1 was used as the group's discussion base, which lead to a theoretical model of the difficulties encountered.

Based on the outputs from the experts’ panel, the questionnaire used in the survey was constructed via Google Forms platform. The questionnaire itself was structured around two parts. The first one focused on the sample’s characterization, such as name, e-mail, years of experience in the subject and relation with the subject. The second part consisted of the twelve difficulties perception level. A scale from 0 to 10 was used so that the respondents could indicate how much they observed of each difficulty when adopting the TPM program. Grade 0 indicates no observation of the difficulty while grade 10 indicates maximum difficulty observed. Following Gil's recommendations (Gil, 2007), the questionnaire was submitted through a pre-test aiming to identify improvement opportunities before its application. All the methodological procedures were approved by an ethics committee.

The questionnaire was then sent to 220 professionals between September and November 2017. The selection of these professionals happened through a platform that includes their résumé, being selected those who had experience in planning and implanting the TPM program. There were 69 valid responses for statistical analysis, resulting in a return index of 31.3%.

The analysis of the data was carried out through structural equations modelling, a statistical approach that tests hypothesis on the relationships between latent variables and observed variables. Among the SEM techniques, two can be emphasized: the covariance-based one (CB-SEM) and the partial least squares methods (PLS-SEM) (Green et al., 2019; Hair et al., 2014; Lin et al., 2019; Wong, 2013). The CB-SEM is a widely used method to confirm or reject theories through hypothesis testing, particularly when the sample is large, the data has normal distribution and the model is correctly specified. However, researches in which it is difficult to fulfil these requirements and with exploratory nature, the use of PLS-SEM, also known as Soft Modelling, is preferable (Lin et al., 2019; Wong, 2013). Therefore, the chosen method was PLS-SEM and the software was SmartPLS 2.0.

The first model to be tested is the theoretical model that resulted from the experts' panel. Moreover, the model's representation was assumed as having reflective relation between the observable variables and the latent variables, or constructs. Since all possibilities of the constructs' domain are represented, therefore it is considered a high correlation between the variables, a interchangeability and that they can also be omitted without altering the meaning of the construct (Hair et al., 2014; Streukens & Leroi-Werelds, 2016; Wong, 2013).

The minimum sample size was determined by the Software G*Power with the recommendations of a multi-linear regression test F, fixed model and R^2 Zero deviation with test power of 80% (Power = 0.80), median effect size 15% (f2 = 0.15) and 5% error probability (R2 = 0.25) (Hair et al., 2014; Ringle, Silva, & Bido, 2014).

The study model and the sample size were defined and the next step is to apply the partial least squares method with the following adjustments (configured in the software): "Path weighting Scheme", Variance 0, standard deviation 1, maximum iterations to converge the model 300 and stop criterion 0.00001, as recommended by Ringle et al. (2014).

After running the PLS algorithm, it begins the model adjustment analyses that are divided into two stages: "Measurement model" and subsequently "structural model". Ringle et al. (2014) define a sequence of steps for better understanding and analyse the results obtained from SmartPLS. These steps are detailed in Figure 1.

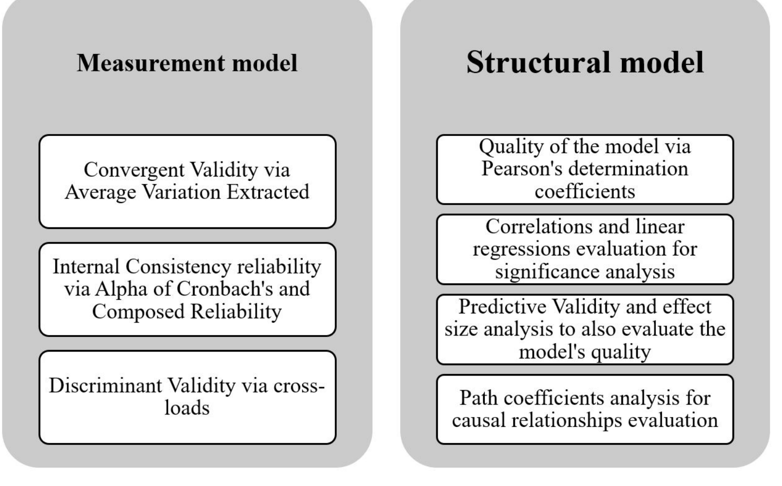

Figure 1. Steps used to validate the model.

The first step to be observed in the measurement model is the Convergent Validity (CV) through the Average Variation Extracted (AVE). The Convergent Validity (CV) is the positive correlation between variables of the same construct (Hair et al., 2014). Constructs must have a value above 0.50, which means that the construct is able to explain more than half of the variables' variance and consequently converge to satisfactory results (Hair et al., 2014; Ringle et al., 2014).

The second step is the analysis of Internal Consistency reliability via Alpha of Cronbach's (AC) and Composed Reliability (CC) (Ringle et al., 2014). Satisfactory values for internal reliability should be above 0.70 and for Composed Reliability from 0.70 to 0.90 (Hair et al., 2014; Ringle et al., 2014).

The third step is to evaluate the Discriminant Validity (VD), which indicates how much a construct distinguishes itself from others, i.e. how unique it is and how much it can capture a phenomenon represented solely by itself and by no other construct of the model (Hair et al., 2014). Through the cross-loads (Chin, 1998), an observable variable must present greater factorial load in its associated construct than in other constructs of the model, meaning that each variable is well allocated in its construct (Hair et al., 2014; Ringle et al., 2014).

At this point, the analysis and adjustments of the "measurement model" are completed and the analyses of the "structural model" initiate (Ringle et al., 2014). The first analysis of this part and the fourth general step is Pearson's determination coefficients (R2) that indicates the quality of the model (Ringle et al., 2014). For the area of social and behavioural sciences, it is suggested the values of R2 = 2%, 13% and 26% for small, medium and large effect, respectively (Cohen, 1988; Ringle et al., 2014).

According to Ringle et al. (2014), SEM uses correlations and linear regressions and thus it should be evaluated whether these relationships are significant. The procedure used to test the significance is the resampling technique bootstrapping, which generates sub samples from the initial samples (Hair et al., 2014). For this survey, the resampling number is 5000 and the number of cases is 69. The fifth analysis, therefore, is the significance test, which analyses whether correlations and regressions are significant at a level of 5%, i.e. valid for 95% of cases (values exceeding 1.96) (Hair et al., 2014; Ringle et al., 2014).

Two more quality indicators of the model's adjustment will be evaluated. Accordingly, the sixth and seventh steps are analyses of Relevance or Predictive Validity (Q2) and the effect size (f2), respectively. Both indicators are obtained from the technique Blindfolding in SmartPLS. The Q2 shows the quality of prediction or accuracy, i.e. shows how much the model approaches the expected. Values greater than 0 should be obtained. The indicator f2 evaluates how much a construct is responsible for the formation of another construct, i.e. checks how much each construct is useful for adjusting the model and in this case, the values can be considered small, medium and large, 0.02, 0.015 and 0.35, respectively (Hair et al., 2014; Ringle et al., 2014).

The last step is the analysis of the path coefficients (Γ). It evaluates the causal relationship between the constructs (Ringle et al., 2014). Coefficients close to 1 represent high positive ratio between constructs (Hair et al., 2014).

Completing all those steps, the model can be validated, and relevant conclusions and discussions can be accomplished.

4 Results and discussion

This section presents the results and discusses them. Initially, it presents the results from the experts' panel, which gave base to the theoretical model followed by all the stages of structural equations modelling.

4.1 Results arising from the Experts Panel

As explained in the previous section, 10 persons participated in the experts' panel. As a result, the difficulties were segregated into two groups called "Difficulties associated with the planning phase" and "Difficulties associated with the implantation phase", presented in Tables 2 and Table 3.

Table 2. Construct "difficulties associated with the planning phase" (DP).

Variables	Parameters
DP_1	Difficulty in selling the project to the company's board, i.e. justifying that improvements in the production indicators will arise from the TPM implantation.
DP_2	Problems in deploying pilot studies as an embryo for subsequent dissemination of the program throughout the company.
DP_3	Low priority in allocating financial resources to TPM implementation.
DP_4	Lack of planning related to targets and goals to be achieved by deploying the TPM program.
DP_5	Lack of training needs' planning.
DP_6	Lack of support by senior management to raise awareness on the importance of the program.

Table 3. Construct "difficulties associated with the implementation phase (DI).

Variables	Parameters
DI_1	Collaborators' resistance related to cultural changes provided by the implantation of TPM.
DI_2	Collaborators' lack of understanding about philosophy, principles and tools that compose the TPM program.
DI_3	Deficient communication and low synergy between areas involved in the TPM implantation.
DI_4	Difficulty in allocating greater responsibility and autonomy to collaborators.
DI_5	Non-compliance to all initially planned sequential stage.
DI_6	Lack of a common language to be used by all employees on the implementation of the program's activities.

The experts have also structured the hypothesis that the first group presents a causal relationship with the second, based on the literature. In addition, the theoretical model and the hypothesis to be tested in structural equation modelling were characterized. Figure 2 introduces the theoretical model.

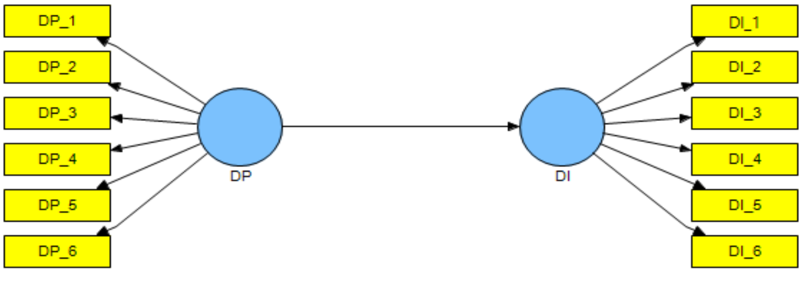

Figure 2. Theoretical model proposed by the experts panel (SmartPLS).

4.2 Results arising from the Structural Equations Modelling

The step after the theoretical model is to calculate the minimum sample size through the software G*Power. Following the recommendations in section 3, a minimum required sample of 55 respondents was found. The 69 answers, therefore, enable the analysis.

The PLS method presented satisfactory results after three iterations. In the first iteration, the average variances extracted (AVE) were less than 0.50 for the construct "difficulties associated with the planning phase". To improve this value, the variable DP_1 with the smallest factorial load was eliminated. In the second iteration, the same construct was still presenting AVE lower than 0.50, and the variable DP_3 was then eliminated. The elimination of the variables with the smallest factorial load to increase the AVE is recommended by Ringle et al. (2014). In the third iteration, there was a convergence and both constructs had an AVE greater than 0.50. Figure 3 shows the model after this first analysis and table 4 introduces the quality criteria.

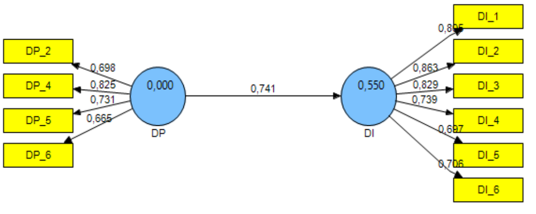

Figure 3. Ajusted measurement model (SmartPLS).

The eliminations from DP_1 and DP_3 recommend by Ringle et al. (2014) can be explained by the literature as part of the DP_6, related to the lack of support by senior management. According to Morales Méndez & Rodriguez (2017), the senior management has the responsibility to provide budget prior to the TPM implementation. Lawrence (1999) defends that top managers should give high priority to maintenance as well as allocate sufficient resources toward the maintenance effort. Furthermore, TPM requires top management commitment, support and strategic planning in the early stage (Hooi & Leong, 2017). It is the responsibility of the top management to spread the benefits of TPM down to the organizational levels and not the other way round (Poduval et al., 2013).

Table 4. Measurement model Quality Criteria.

Constructs	AVE	Composite reliability	Cronbach's alpha
DI	0.601339	0.899910	0.865615
DP	0.536095	0.821155	0.711326

The AVE from both constructs are in accordance with the criterion greater than 0.50 which means that the model converges to satisfactory results (Ringle et al., 2014). The values for internal reliability fall within 0.70 and for Composed Reliability between 0.70 to 0.90 (Hair et al., 2014; Ringle et al., 2014), meaning that the sample does not contain bias and the responses are reliable (Ringle et al., 2014).

The Discriminant Validity was analysed through Chin's cross-load criterion (1998). Table 5 shows that the largest factorials loads for each difficulty occur in the designated construct, meaning a correct allocation by the experts.

Table 5. Measurement model crossed loads.

Variables	DI	DP
DI_1	0.804684	0.553788
DI_2	0.862758	0.604032
DI_3	0.828715	0.608124
DI_4	0.738801	0.460536
DI_5	0.696638	0.582268
DI_6	0.705882	0.607244
DP_2	0.484717	0.698105
DP_4	0.637617	0.825458
DP_5	0.583124	0.730607
DP_6	0.436589	0.664727

At this point, the adjustments and analyses of the measurement model are concluded and the structural model analysis begins (Ringle et al., 2014). In this step, the Pearson determination coefficient for the endogenous latent variable (construct DI) was analysed and indicates the quality of the adjusted model. The obtained value has a high effect of R2 = 55% and meets the Criterion of Cohen (1996 *apud* (Ringle et al., 2014)). Performing the resampling method, the bootstrapping, is possible to analyse whether correlations and regressions are significant and valid for 95% of cases, i.e. present values t-student above 1.96 (Ringle et al., 2014). For the relationship between the constructs DP and DI, the value of 14.275 was obtained. For the variables, the values have also shown themselves satisfactory, affirming that correlations and regressions are valid for all relationships.

Following the analysis, the indicators of relevance or predictive validity (Q2) and the effect size (f2) were evaluated through the technique Blindfolding resulting in Q2 (DI = 0.299781 and DP = 0.233315) and f2 (DI = 0.437599 and DP = 0.233315), which are appropriate results.

Finally, the analysis of the path coefficient between the constructs DP and DI is carried out. It is possible to observe a high value (0.741) for the mentioned coefficient, which supports the causality relation of the constructs. This value is close to 1.0 and can be considered as a strong relationship, which proves that the difficulties of the implementation phase have a strong causality relation to the planning phase. The literature corroborate this finding since some authors defend that the failure of TPM implementation is directly related to the lack or ineffectiveness planning (Bartz et al., 2014; da Costa et al., 2015; Piechnicki, 2013; Piechnicki, Sola, & Trojan, 2015; Singh et al., 2016). In the validated model, 4 obstacles represent the difficulties of planning (DP) and 6 are necessary to represent the difficulties of implantation (DI). The intensity of each validated difficulty is presented in Figure 4 through the averages arose from the notes attributed by the respondents.

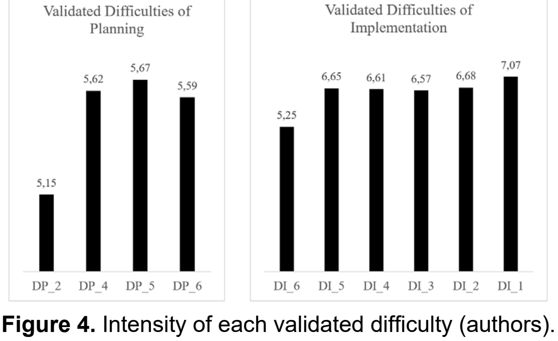

Figure 4. Intensity of each validated difficulty (authors).

The difficulties of the planning phase vary around values from 5.15 to 5.65, being DP_4: "Poor planning related to targets and goals to be achieved by deploying the TPM program." the one with the largest associated average. Related to the difficulties associated with the implantation phase of the TPM program, the variation was higher between values from 5.25 to 7.07. The most observed difficulty was the DI_1, concerning the collaborators' resistance related to the cultural changes provided by the implantation of the TPM program. Furthermore, this result agrees with Table 1, where the parameter DI_1 was cited by the larger number of different authors.

5 Conclusions

This article aimed to evaluate the main difficulties when adopting the TPM program and to prove the hypothesis that difficulties associated with the planning phase have a causal relationship with difficulties associated with the implantation phase. Through the presented the results, the goals were achieved.

The proposed model and the allocation of difficulties in thematic constructs, built by the experts' panel, was correct and for the difficulties associated with the planning phase four variables are sufficient for analysis, since the two eliminated ones are already represented by the others. The path coefficient 0.741 clearly highlights the causality ratio, proving the assumptions made by experts were correct. The literature reinforces this result, emphasizing that the appropriate planning is crucial for the success of TPM adoption, that the difficulties are present at all levels of organizations (strategic, tactical and operational) and TPM is a management model to be adopted over the entire organization, not only as a simple maintenance tool.

The results can be used by others as a starting point to structure new tools and models associated with the program. The authors of this article, once again, emphasize the exploratory character of this research. It should be noted that for different samples and different profiles of respondents, the results may vary slightly. It is suggested that, for future works, maturity models of the TPM program be developed, as well as tools that allow greater integration between the mentioned program and other management techniques. Finally, future studies should provide an in-depth overview of the main difficulties, and to propose a wide range of solutions.

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