Organizational Digital Transformation Framework for integrating BPM, Digital Technologies, and Human Factors using SEM

Camilla Buttura Chrusciak[1*][0000-0002-7650-3312], Anderson Luis Szejka[1][0000-0001-8977-1351] and Osiris Canciglieri Junior[1][0000-0002-8503-9275]

[1]Industrial and Systems Engineering Graduate Program (PPGEPS), Pontifical Catholic University of Parana (PUCPR), Curitiba, Brazil
camilla.chrusciak@pucpr.edu.br,
{anderson.szejka;osiris.canciglieri}@pucpr.br

Abstract. Digital transformation has generated profound structural changes in companies, impacting their products, processes, and services. It involves the integration of emergent technologies into all aspects of the companies, changing how work is done. From automating repetitive tasks to implementing data-driven decision-making processes, digital transformation optimizes workflows, fosters innovation, and drives competitive advantage. The study hypothesizes that effective technology implementation with employee engagement, usability awareness, and strategic management practices enhances digital transformation outcomes. Therefore, this research investigates the influences and correlations within four key domains: digital transformation, human factors, business process management, and emerging technologies. In this way, a literature review in the Scopus and Web of Science databases identified relevant articles aligning with the investigation's scope. The content analysis allowed us to determine elements and parameters that would serve to employ Structural Equation Modeling (SEM), a robust multivariate data analysis approach designed for exploring complex relationships. The results indicate that digital tools optimize operations and decision-making processes, aligning with user experience principles to mitigate cognitive overload. In addition, this research underscores the importance of considering human factors in technology implementation, aiming to guide companies in balancing efficiency with employee cognitive load. Finally, future work will propose the conceptual framework to ensure its practical applicability in enhancing human experience in digitally transformed organizations.

Keywords: Digital Transformation, Business Process Management, Human Factors, Structural Equation Modeling.

1 Introduction

Digital Transformation (DT) can be conceptualized as enhancing an organization by establishing significant changes in its attributes through the combination of information technology, computing, communication, and connectivity [1]. This approach is grounded in various technologies and procedures designed to create more efficient value for customers and businesses [2].

DT refers to integrating digital technologies and business processes in a digital economy [3], and it has influenced the world of work. As companies adopt digital technologies and automatize procedures, employees face alterations in their usual patterns and duties. These technologies can be simultaneously constructive and detrimental to personnel and their cognitive abilities [4]. Overall, technology continues redefining the employment landscape in complex ways. Lower-skilled roles may become obsolete and require retraining, but new domains and high-level jobs emerge [5]. Adaptability will be crucial as digital progress shapes future occupations and the daily work experience evolves. Societal support networks can help smooth this transition while empowering humans to focus energies on tasks best suited for human skills and perspectives. Moreover, low job control was more aversive regarding the psychological well-being of technologically fast workers than technologically slow workers [5]. In this way, the loss of control oversteps automated by machines seemed to have a more intensive effect than low control [6].

Some examples of negative impacts of DT for workers include information overload and multitasking, where DT can lead to increasing quantities of information for workers to manage and process. Constant digital connection and the pressure for multitasking may cause cognitive overload, stress, and decreased productivity [7]. Another potential impact is associated with an accelerated pace of work, in which the digitization of processes often increases efficiency and speed in operations. This may lead to an accelerated work pace with shorter deadlines and urgent demands. The worker may feel the need to produce more in less time, which would result in burnout and exhaustion [8]. The work step accelerates with digitization, including fast responses and agile decision-making. This scenario may enhance the cognitive load of the worker, leading to stress and mental fatigue [8].

These examples highlight how Digital Transformation can increase workers' cognitive load due to information overload, multitasking, pressure, and other factors. Therefore, organizations must recognize these challenges and implement appropriate strategies to manage cognitive load, creating a balanced and healthy work environment for employees [9].

Based on this context, this research identifies the complex relationships with the indicators of DT, human factors (HFE) impacts and Business Processes Management (BPM) to guide the design of an integrated framework for Organizational Digital Transformation. This framework will provide valuable guidance to organizations, offering insights for the strategic development of organizational capabilities that align with the dynamic nature of the digital transformation process, aiding data-driven decision-making, and educating workers' cognitive load and interpretation errors.

To analyze the relationships among the indicators, we used Structural Equation Modelling (SEM), a multivariate technique increasingly utilized in scientific inquiries to examine and assess complex causal relationships. Distinguished from other modelling methodologies, SEM evaluates both direct and indirect effects within pre-established causal frameworks. SEM has evolved through three generations, with roots tracing back a century, underscoring its enduring relevance and methodological advancements [10].

The paper is structured as follows: Section 2 addresses the problem statement regarding human factors' impacts in the workplace. Section 3 presents a literature review and the SEM method. Section 4 is devoted to the application of the SEM.

Section 5 discusses the main results and existing gaps in related works. Finally, section 6 concludes and presents perspectives for the research continuation.

2 Problem Statement

Corporate activities and projects are conducted in the workplace, encompassing remote and physical environments. It also includes various physical, psychological, social, and organizational aspects that constitute the corporate environment, such as organizational climate, operational procedures, organizational culture, ergonomics, and safety, among others (Fig. 1). All these factors are integral components of the environment and directly influence the functioning of a company [11].

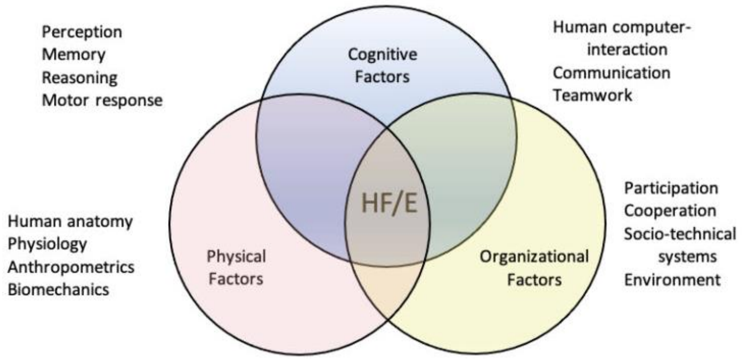

Fig. 1. Domains of HFE (Human Factors/Ergonomics).

For example, employees may experience time pressure, rapid decision-making, and intensive physical movement. Furthermore, temperature, humidity, lighting, noise, and others contribute to the workshop environment, frequently leading to discomfort. These and other factors can have cognitive impacts on employees and their work. Human cognitive capabilities and limitations should be considered in the design of work systems [11].

Workers cognitive aspects include perception, memory, reasoning, information processing, and decision-making. Insufficient attention to these requirements can cause stress and jeopardize psychological health and the ability to perform work tasks [12,33]. Because humans have limited visual processing capacity, other sensory modes, such as auditory and tactile displays, should facilitate identification and attention, especially when the visual channel is highly loaded.

In [12], the authors define some strategies for cognitive capabilities and limitations across industries and jobs. Some examples: (i) Design information systems for ease of comprehension, using coding techniques such as size, shape, colour, and position to indicate the meaning of numerical values displayed on screens or dials; (ii) Design new work systems so that skills transfer as much as possible from previous systems. This example will enhance learning, reduce training time, and minimize opportunities for errors.

Work systems increasingly incorporate technological tools like robotic, intelligent, and autonomous systems, Augmented Reality or Virtual Reality (AR/VR), and wearable devices (exoskeletons). While these tools can reduce short-term risks in the workplace, they also bring new considerations and challenges for human cognition and potential long-term physical risks. Incorporating them into work system design should prioritize enhancing human performance without hindering it. International Organization for Standardization (ISO) (e.g., ISO 9241-11:2021) addresses cognitive and physical issues related to these technologies, such as ensuring human readiness to take control if automation fails and managing cognitive workload. When integrated appropriately, these technologies can significantly enhance worker capability [12].

In this context, considering the scenario of human factors in the workplace and the ongoing adoption of technologies to achieve the digital transformation of a company, the research problem explored in this study is: "*How can Digital Transformation and its Emerging Technologies improve efficiency in organizational management while minimizing cognitive impacts on employees in companies?*".

3 Materials and Methods

3.1 Systematic Literature Review Protocol

This section will provide a systematic literature review (SLR) on DT, HF, BPM and Technologies and define relevant research analysis for a conceptual framework proposal. The SLR must be strictly planned to cover all the literature to identify the main contributions related to the research. In this way, this research carried out an extensive literature review based on two studies' guidelines: i) [13] which recommend the use of frequently cited bibliographies and journals with a high impact factor to obtain a high-quality review, and ii) [14] which uses three main stages for literature review (1) literature review planning, (2) literature review conducting and (3) report (content analysis). A comprehensive and complete SLR has been conducted and is detailed in [15]. In brief, the methodology employed is illustrated in Fig 2.

To summarize, after analyzing the selected articles, the results of SLR showed that the impact of Digital Transformation on human factors presents a rich landscape for further study. The positive aspects, such as increased efficiency and flexibility, offer opportunities to enhance workplace productivity and employee well-being. However, the negative consequences, including skill inequality, information overload, accelerated work pace, changes in work relationships, and cognitive load, reveal significant gaps in our understanding of navigating this digital landscape effectively.

Future research should focus on developing strategies to mitigate these negative effects, promote skill development for all, and create a balanced work environment that harnesses the benefits while addressing the challenges of the Digital Transformation era. This evolving field presents an exciting avenue for exploration and innovation in optimizing the human experience in the digital era. These results revealed the need for research that employs conceptual frameworks that effectively integrate human-centred design principles into implementing digital technologies within organizational contexts.

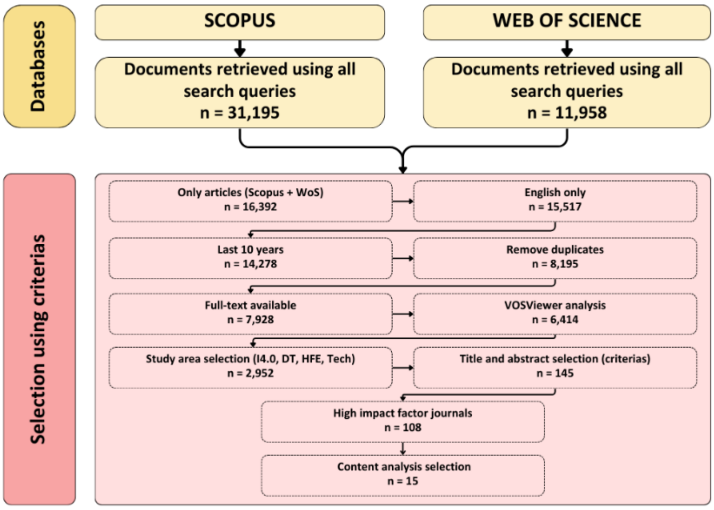

Fig. 2. Systematic Literature Review flowchart steps.

3.2 Partial Least Squares Structural Equation Modelling

Based on the theoretical study in the previous section, this research developed the hypothesis to examine the relationship between the DT and the relation among HFE, BPM and technologies. The hypotheses (H) of the model were formulated for testing in this research are detailed below:

- **H1**. The effective implementation of technologies, coupled with employee engagement and interoperability, drives the efficiency of digital transformation, promoting a user-friendly integration of processes with employees.
- **H2**. Employee awareness of digital transformation goals and the usability of technologies are essential for the success of digital transformation, promoting better adaptation to new platforms while potentially reducing the cognitive load associated with activities.
- **H3**. Implementing management technologies can result in significant gains in operational efficiency and improve decision-making through real-time analysis.
- **H4**. The effective implementation of BPM practices can result in improvements in the company's operational efficiency and enable quick adaptation to change in market conditions.

Therefore, in the following section, this paper describes the quantitative method used in this study. It is the most relevant selection method due to the research domain, data types, respondents' category, group, and data analysis tools and techniques.

4 Development of PLS-SEM

To start a project, we must prepare the path model demonstrating the relationship between the constructs. In PLS-SEM, the term construct is used to describe a variable that is not directly measured by indicators and, for that reason, is referred to as a latent variable [10]. The structural equation modelling framework is subdivided into the structural and measurement models. The structural model specifies the relationships between the latent variables (constructs). In contrast, the measurement model specifies how the observed variables (indicators) measure the latent variables, describing their validity and reliability [16].

We must prepare the structural model to initiate the modelling process, demonstrating the relationships between the constructs. In PLS-SEM, the term "construct" describes a variable that is not directly measured and is therefore referred to as a latent variable. In this research, the pillars of RSL defined the constructs: Digital Transformation/Industry 4.0, Business Process Management, Emerging Technologies, and Ergonomics/Human Factors. These constructs were related, as presented in Figure 3. This relation was created based on the SLR results.

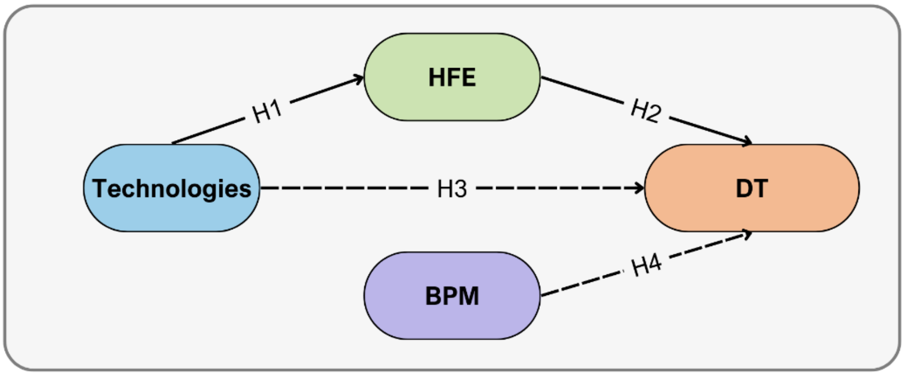

Fig. 3. PLS-SEM structural model

Thus, this model evaluates the proposed pathway (H1+H2) that effectively integrates human-centred design principles into implementing digital technologies within organizational contexts. This model means understanding how people interact with digital technologies in organizations and how this interaction can be made more effective and cognitively friendly. The model considers aspects such as people's cognitive thinking and how the organization can be affected by introducing new technologies in pursuit of digital transformation.

This approach represents a more comprehensive view compared to other existing approaches analyzed in the literature, such as the role of emerging technologies in digital transformation (H3) and BPM as an effective management strategy to achieve company objectives (H4). In other words, this model seeks to look beyond the simple implementation of technologies and management strategies.

Next, a set of indicators is necessary to measure the constructs. Indicators that cause the latent variable are called formative indicators. Conversely, indicators that are caused by the latent variable are called reflective indicators. To measure the latent variables, the indicators presented in Table 1 were created, and in this study, all indicators are reflective, meaning their respective areas of study cause them. These indicators were created based on the content analysis of the articles resulting from the SLR, where the authors indicated in their research the benefits (gains), statements, and improvements generated regarding each latent variable.

Table 1. Indicators for each latent variable

Code	Indicators	Ref
DT1	By optimizing operations, digital tools contribute to more efficient execution of daily tasks.	[17]; [31]; [30]; [29]
DT2	Digital transformation drives value generation, helping the company align with market needs.	[23]; [22]; [24]
DT3	Digital transformation streamlines internal processes, improving company productivity.	[25]; [24]; [17]
DT4	Process automation enables replacing manual tasks with automated systems, providing efficiency, error reduction, and agility in task execution.	[17]; [18]; [19]; [21]; [22]; [23]; [24]; [25]; [26]; [27]; [28]; [29]
DT5	Data collection and analysis facilitate informed decision-making, driving more effective strategies.	[23]; [26]
HFE1	Investing in human factors promotes an engaging work environment, resulting in more productive and motivated employees.	[19]; [18]; [31]; [21]; [28]; [24]; [29]; [27]; [30]; [25]; [17]
HFE2	Human factors contribute to developing a strong organizational culture, with shared values and alignment of objectives.	[18]; [30]; [28]; [25]
HFE3	The participatory and human-centred approach aims to integrate the perspectives and experiences of individuals directly involved, promoting active collaboration and ensuring that solutions and decisions reflect user needs.	[19]; [18]; [28]; [24]; [29]; [27]; [17]
HFE4	Human-technology interaction seeks to create a harmonious relationship, facilitating the intuitive and beneficial use of technologies to improve workers' lives and experiences.	[18]; [31]; [21]; [28]; [29]; [30]
HFE5	Usability and user experience are significant factors regarding employees' use of technologies.	[18]; [31]; [28]; [29]; [27]; [30]; [25]
TEC1	Using indicators for business process management contributes to monitoring a company objective's performance level or success.	[18]; [30]; [28]
TEC2	Strategic planning can result in significant improvements in company operational efficiency.	[17]; [18]; [26]; [31]; [21]; [22]
TEC3	Effective collaboration within a business ecosystem contributes to value aggregation and alignment of company demands.	[17]; [18]; [25]
TEC4	The process management approach constantly aims to promote a culture of continuous improvement to adapt to changes and challenges in the business environment.	[17]; [18]; [24]; [25]
TEC5	Effective management includes detailed mapping and documentation of each process, providing transparency and a clear understanding of the steps involved.	[19]; [18]; [20]; [21]; [28]; [24]; [29]; [17]
BPM1	Process automation through technologies can reduce errors and increase consistency in operations.	[17]; [18]; [19]; [20]; [21]; [22]; [23]; [24]; [25]; [26]; [27]; [28]; [29]; [30]; [31]
BPM2	Interoperability allows various systems to communicate with each other and share information in real time.	[19]; [18]; [31]; [21]; [28]; [23]; [24]; [29]; [30]; [25]; [26]; [17]
BPM3	Investing in cybersecurity and protecting the company from cyber threats is essential to keep sensitive data safe.	[18]; [19]; [20]; [27]; [25]

Code	Indicators	Ref
BPM4	Technologies like Big Data directly contribute to operational efficiency, enabling more effective data management.	[18]; [20]; [22]; [28]; [23]; [27]; [25]; [26]
BPM5	Using technologies provides access to real-time data and advanced analytics, facilitating informed and evidence-based decision-making.	[23]; [26]

With the indicators defined, the measurement model can be established and used to assess the relationships between indicators and their corresponding constructs (Fig. 4).

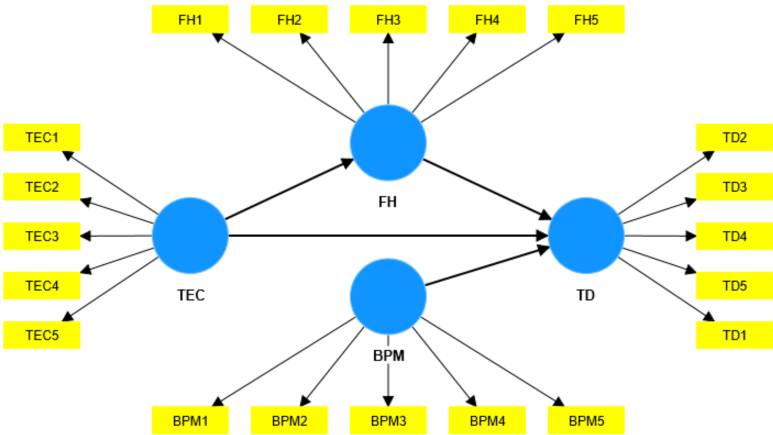

Fig. 4. PLS-SEM measurement model

4.1 Data collection

After the structural and measurement models were specified, a survey was conducted, utilizing a structured questionnaire as the data collection instrument, through which information was requested from the group of respondents regarding the studied problem. Conclusions about the collected data were drawn through quantitative analysis. The sample was chosen by convenience, meaning it is non-probabilistic.

The questionnaire was emailed to a network of contacts in the industry, especially those connected to the industrial engineering field. These contacts, in turn, shared the questionnaire with colleagues in their respective sectors. Recipients included multinational companies, research groups, students, and professors from the Industrial and Systems Engineering Graduate Program at PUCPR. Additionally, the questionnaire was made available to members of the Brazilian Ergonomics Association (ABERGO), aiming to ensure the participation of experts from all relevant areas for the analysis.

For the evaluation of statements (indicators), a Likert scale with five response options was employed. According to [32], Likert is a scale that attempts to measure attitudes or opinions, where five points are used to assess the strength of agreement or disagreement of a person with a set of statements. In this research, the agreement scale was defined as follows: (1) strongly disagree; (2) disagree somewhat; (3) neither agree nor disagree; (4) agree somewhat; and (5) strongly agree.

As a result, 134 complete responses were obtained. Respondents who left questions unanswered were excluded from the sample, thus ensuring the integrity of the analyzed data.

4.2 Measurement Model Evaluation

With the collected data, the next step is to execute the PLS-SEM algorithm and, based on the results, evaluate the reliability and validity of the construct measures in the measurement model.

According to [10], the first evaluation should focus on internal consistency reliability. The internal reliability of the constructs was verified through Cronbach's Alpha and Composite Reliability indicators. Both indicators assess whether the sample has biases and whether the observed variables can generate reliable information [10]. Composite reliability values from 0.60 to 0.70 are acceptable in exploratory research, while values between 0.70 and 0.90 can be considered satisfactory in more advanced stages of study [10]. As can be observed in Figure 5, the constructs in the model developed for this study exhibited adequate internal reliability.

The second criterion to be analyzed is convergent validity, assessed through Average Variance Extracted (AVE). In this regard, a value of 0.50 or higher indicates that, on average, the construct explains more than the average variance of its indicators [10], with this being the minimum acceptable value for AVE. As shown in Figure 5, the values found in the constructs were satisfactory.

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BPM	0,824	0,832	0,876	0,588
FH	0,796	0,810	0,859	0,550
TD	0,775	0,772	0,847	0,528
TEC	0,808	0,828	0,865	0,563

Fig. 5. Reliability and validity

The third and final criterion to be analyzed is discriminant validity, assessed using the Fornell-Larcker criterion, which compares the square root of the AVE with the correlations between latent variables [10]. Figure 6 presents the square root of the AVE for the model's constructs. It can be observed that the values of the square roots of the AVE for each construct are greater than the correlations with other constructs. Thus, it is confirmed that the model has discriminant validity per the Fornell-Larcker criterion, a more conservative approach to ensure discriminant validity [10].

	BPM	FH	TD	TEC
BPM	0,767			
FH	0,504	0,741		
TD	0,475	0,395	0,726	
TEC	0,608	0,435	0,622	0,750

Fig. 6. Correlation between latent variables

With these results, it is evident that the measurement model exhibits quality and confirmed validity, and now we proceed to the analysis of the structural model.

4.3 Structural Model Evaluation

The first analysis at this stage is the assessment of Pearson's determination coefficients (R^2): R^2 evaluates the portion of the variance in endogenous variables explained by the structural model. R^2 ranges from 0 to 1, with higher values indicative of greater explanatory power. As a general guideline, R^2 values of 0.75, 0.50, and 0.25 can be considered substantial, moderate, and weak, respectively [32].

In Figure 7, the values presented within the blue circles indicate how much of the variance of the latent variable is explained by the other latent variables contained in the structural model. In contrast, the values presented on the arrows, referred to as path coefficients (β), explain the strength of the effect of one construct on the others. Evaluating the degree of variance explanation of the target endogenous variable, in this case, TD, the R^2 was 0.412, which allows us to conclude that the three latent variables evaluated (TEC, FH, and BPM) weakly explain 41.2% of the variance of TD moderately.

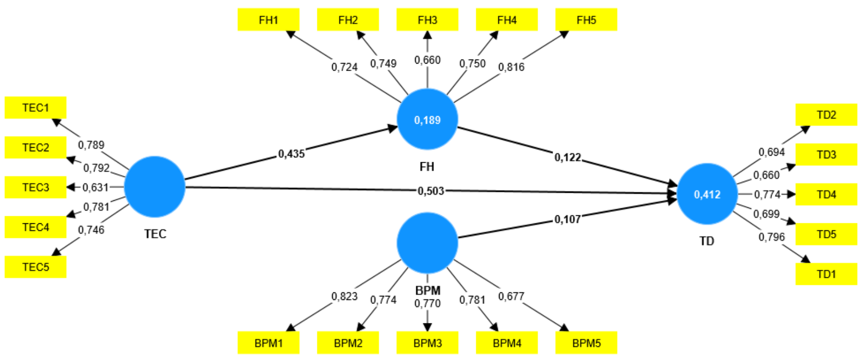

Fig. 7. PLS-SEM results

According to [10], path coefficients are standardized values ranging between -1 and 1, where estimates close to 1 represent a strong positive relationship (and vice versa for negative values), and the closer to zero, the weaker the relationship. When analyzing the path coefficients in Figure 7, it is observed that the relationship TEC>TD, referring to H3, has a moderate relationship (β = 0.503). However, when analyzing the path TEC>FH>TD, referring to hypotheses H1+H2, the relationship is stronger (β = 0.557) than the TEC>TD path alone since the sum of the path is greater. This analysis indicates that the path with the better result is more recommended, as the relationships between the variables are more satisfactory when seeking the outcome of digital transformation.

Furthermore, when analyzing each construct's observed variables (indicators), all indicator loadings should be statistically significant, with standardized loadings expected to exceed 0.708. Indicators with loadings between 0.40 and 0.70 should be scrutinized and eliminated only if they impact the reliability and quality of the model [32].

Most indicators exhibited loadings exceeding 0.708; only indicators TEC3, FH3, BPM5, TD2, TD3, and TD5 showed values slightly below but very close to the recommended value. Additionally, the model demonstrated satisfactory Cronbach's Alpha, Composite Reliability, and AVE; the indicators were retained for these reasons.

Finally, examining the highest loadings of the indicators for each construct, we have indicators TD1 (By optimizing operations, digital tools contribute to more efficient execution of daily tasks), FH5 (Usability and user experience are significant factors regarding the use of technologies by employees), TEC2 (Interoperability allows various systems to communicate with each other and share real-time information), and BPM1 (The use of indicators for business process management contributes to monitoring the level of performance or success of a company's objective).

5 Discussion of Results

Therefore, it is concluded that within the context delimited by the entire Systematic Literature Review and Content Analysis of this research, digital tools are necessary for process optimization and the effectiveness of daily tasks. These tools must align with usability and user experience principles to establish a more harmonious interaction and minimize potential cognitive effects associated with their use. Additionally, using strategic indicators (KPIs) makes monitoring and evaluating progress towards desired outcomes possible, enabling more assertive decision-making.

Furthermore, interoperability is essential in promoting the integration and efficiency of operational systems. By enabling communication and real-time information sharing among different systems and sectors, interoperability facilitates collaboration and fosters a unified view of organizational operations.

Based on the results obtained through PLS-SEM, it is possible to develop a conceptual framework aligned with the specific objectives of this research. This framework will provide a solid theoretical structure that enables a better understanding of the relationships between the studied variables and facilitates the interpretation of the results obtained.

6 Conclusion

In conclusion, the discussion highlights the importance of considering human factors in technological implementations for successful digital transformation. The undeniable impact of Industry 4.0 technologies in the manufacturing sector presents significant opportunities to analyse hypothetical relationships created from the indicators presented in this study and assess them, thus defining the most relevant interactions in this context. Subsequently, proposing a framework that considers human factors when applying these technologies is crucial, aiming for digital transformation and human well-being.

This study addresses social aspects related to implementing digital technologies in the workplace. It considers the impact of these technologies on workers' quality of life and changes in the job market due to automation. Additionally, it highlights the importance of understanding and incorporating changes in social behaviour caused by digital advancements. The study examines digital transformation's technical and organizational implications and social aspects.

As future research, the next steps involve elaborating the conceptual framework derived from the PLS-SEM results. This framework will comprise a systematic arrangement of variables and their interrelationships, providing a comprehensive overview of the research domain. Each framework component will be meticulously defined, drawing upon theoretical foundations and empirical evidence uncovered in the study. Furthermore, the framework will be subjected to rigorous validation procedures to ensure its robustness and applicability. Once finalized, the conceptual framework will guide future research endeavours and practical implementations for companies.

Acknowledgement. The authors especially thank the support of the Pontifical Catholic University of Paraná (PUCPR) – Industrial and Systems Engineering Graduate Program (PPGEPS). This project is sponsored by the MAI/DAI Academic Master's and Doctoral Program for Innovation from the Ministry of Science, Technology, Innovation and Communications and the National Council for Scientific and Technological Development (CNPq).

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