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A Study on the Determinants that Influence Digital Transformation Adoption among Malaysia's Manufacturing Firms

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Abstract

Purpose: This study aims to examine the factors influencing the adoption of digital transformation in Malaysian manufacturing firms. By integrating the Technology-Organization-Environment (TOE) and Human-Organization-Technology (HOT-fit) frameworks, this conceptual paper seeks to understand how various organizational, technological, environmental and human factors contribute to successful digital transformation adoption. **Design/methodology/approach:** Using a deductive approach, hypotheses were developed based on existing literature. Data will be collected via a cross-sectional survey targeting Chief Technology Officers (CTOs) and senior managers from manufacturing companies listed in the Federation of Malaysian Manufacturers (FMM) directory. Structural equation modeling (SEM) with Partial Least Squares (PLS) will be used to analyze the relationships among digital transformational leadership, organizational agility, cost, competitive pressure and digital transformation. **Expected Findings:** Digital transformational leadership, organizational agility and competitive pressure significantly influence digital transformation adoption positively, while cost will negatively impact adoption of digital transformation. **Research limitations/implications:** Limited to Malaysian manufacturing firms, which may affect the generalizability of findings to other sectors or regions. Future research could expand to different industries and areas, and longitudinal studies could provide deeper insights into the dynamic nature of digital transformation. **Practical implications:** The research offers insights for policymakers and business leaders in the manufacturing sector, emphasizing the need for digital transformational leadership, organizational agility, healthy competitive pressure and low technological infrastructure investment. It provides a comprehensive understanding of the interplay between technological, organizational, environmental and human factors, aiding effective digital transformation strategies. **Originality/value:** This study integrates the TOE and HOT-fit theories, empirically testing their applicability in digital transformation adoption

within manufacturing firms. It lays a foundation for future research and practical applications in enhancing digital capabilities and competitiveness.

Keywords: Factors, Human, Digital Transformation, Manufacturing, Malaysia

Introduction

Digital transformation (DT) has emerged as a critical imperative for manufacturing industries worldwide, propelled by the transformative potential of advanced digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics. This paradigm shift, often referred to as "Industry 4.0," promises substantial enhancements in operational efficiency, supply chain management, and customer engagement (Battistoni et al., 2023). Governments, including those in emerging economies, are actively supporting DT initiatives to enhance local industrial competitiveness in the global market (Albukhitan, 2020). Despite the significant benefits promised by DT, its successful implementation poses intricate challenges, requiring meticulous strategic alignment, organizational restructuring, and technological integration (Favoretto et al., 2021).

In Malaysia, as in many other countries, manufacturing firms are increasingly turning to DT to navigate competitive pressures and seize new growth opportunities. However, the path to successful DT adoption is fraught with complexities unique to each organizational context, including regulatory landscapes, cultural nuances, and industry-specific dynamics. McKinsey & Company (2018) underscores that DT surpasses conventional organizational change efforts, necessitating profound shifts in business models and operational frameworks. These transformations often entail the daunting task of reconfiguring legacy systems and establishing robust digital infrastructures capable of supporting agile, data-driven decision-making (Little & Deokar, 2016).

Moreover, the digitalization of manufacturing processes blurs traditional organizational boundaries, fostering collaborative ecosystems where firms co-create value through interconnected networks (Plekhanov et al., 2023). This paradigm shift in business operations prompts critical questions about governance, economic distribution, and the strategic positioning of firms within evolving digital landscapes. Therefore, there is a compelling need for empirical research that not only identifies the determinants of DT success but also develops robust frameworks and metrics to assess and guide DT initiatives within the Malaysian manufacturing context.

This study aims to address these gaps by proposing a multidimensional framework integrating technological, organizational, human, and environmental perspectives within the TOE and HOT-fit models. By conducting a comprehensive review of existing literature and empirical data, this research seeks to identify and prioritize the factors critical to DT adoption in Malaysian manufacturing firms such as cost, organizational agility, competitive pressure and digital transformational leadership. The findings will contribute to a deeper understanding of how firms can strategically leverage DT to enhance competitiveness, sustainability, and resilience in an increasingly digitalized global economy. Such insights are essential for policymakers, industry leaders, and researchers aiming to foster sustainable growth and innovation in Malaysia's manufacturing sector amidst rapid technological advancements and global market uncertainties.

Literature Review

Digital transformation refers to the use of digital technologies to create new or modify existing business processes, culture, and customer experiences to meet changing business and market requirements (Vial, 2019). In the manufacturing sector, this transformation can lead to significant improvements in operational efficiency, product quality, and customer satisfaction (Lichtenthaler, 2020). However, the adoption of digital transformation technologies in manufacturing firms is influenced by various factors, which can be categorized into technological, organizational, and environmental contexts as per the TOE framework (Tornatzky & Fleischer, 1990).

Digital transformation (DT) in the manufacturing sector refers to the adoption of digital technologies to innovate business models, often synonymous with the "Industry 4.0" paradigm. This global trend is bolstered by government initiatives, even in emerging economies, aimed at bolstering local industries' competitiveness in the global market (Albukhitan, 2020). Researchers assert that DT in manufacturing involves the integration of cutting-edge technologies like artificial intelligence (AI), phygital solutions (combining physical and digital elements), and the Internet of Things (IoT), facilitating significant enhancements across supply chains, manufacturing processes, and customer interactions (Battistoni et al., 2023). Key technologies underpinning Industry 4.0, such as IoT for real-time data analytics, horizontal and vertical system integration for seamless operations, big data analytics for predictive insights, and autonomous robots for enhanced productivity, empower manufacturing firms to achieve greater agility and responsiveness to market dynamics (Little & Deokar, 2016).

Despite widespread interest and potential benefits, DT initiatives in manufacturing encounter multifaceted challenges, including strategic alignment, organizational restructuring, and technological integration hurdles (Verhoef et al., 2019). McKinsey underscores the complexity of DT efforts, noting their disruptive nature and the necessity for fundamental shifts in business models, often necessitating the overhaul of legacy systems and operational frameworks (McKinsey & Company, 2022). Moreover, the digitalization of manufacturing processes blurs traditional organizational boundaries, fostering a shift towards collaborative ecosystems where firms co-create value through interconnected networks (Plekhanov et al., 2023). This transformation poses governance challenges and prompts reconsideration of economic dynamics within digital ecosystems, highlighting the need for comprehensive research into organizational dynamics in the digital age.

In addressing these complexities, Favoretto et al (2021), conducted a systematic review of 176 studies to identify common challenges and strategic imperatives for successful DT adoption in manufacturing. They emphasize the necessity for tailored approaches that consider local nuances and industry-specific factors in Malaysia to effectively navigate the digital transformation landscape. Ghobakhloo and Iranmanesh (2021), underscore the absence of a universally accepted metric for assessing "digital transformation success," suggesting the development of standardized frameworks and empirical evaluation tools as crucial for future research. Additionally, Battistoni et al (2023), acknowledge limitations in their study's focus, particularly regarding the inclusivity of organizational variables beyond small and medium-sized enterprises (SMEs) and size-related considerations, prompting calls for broader applicability and relevance in the Malaysian manufacturing context.

Understanding these factors is pivotal for devising contextually appropriate strategies that leverage DT to maximize competitive advantage amidst local regulatory frameworks, cultural dynamics, and industry-specific challenges.

Underpinning Theory

To construct a measurable framework for this study on digital transformation adoption in manufacturing firms, it is essential to identify appropriate organizational-level theories. These theories view technology adoption from a broader perspective, focusing on social processes, structures, and their interrelationships within a community or business entity. Two relevant theories for this study are the Technology-Organization-Environment (TOE) framework and the Human-Organization-Technology fit (HOT-fit) theory (Saleh et al., 2018). Existing technology adoption theories often address only one or two dimensions, neglecting the interrelationships among key factors.

The TOE framework, developed by Tornatzky et al (1990), aims to understand the elements influencing new technology adoption within organizations. This framework posits that technological innovation can be anticipated from three angles: technology, environment, and organization. It is widely recognized and applied in firm-level technology or innovation adoption studies across various contexts. Technology factors include on-premises and off-premises technologies, the organizational perspective involves firm characteristics, and the environmental perspective encompasses the organization's operational domain and structure (Tornatzky et al., 1990).

The phenomenon of 'heterogeneity of IT adoption' demonstrates that some ITs are more successfully adopted than others, even within similar organizations (Dost et al., 2020). This complexity involves intertwining organizational, technological, and personal factors (Ferreira et al., 2021). Xu and Lu (2022), stress the importance of alignment among these forces, noting that misalignment can undermine IT adoption. Human factors play a crucial role, as technology that fails to meet users' needs may struggle to sustain itself (Boudreau & Robey, 2005). Unfortunately, users' preferences, knowledge, and skills are often overlooked in IT design and development. Additionally, many IT implementations lack alignment with an organization's strategy, structure, and processes (Leidner et al., 2020). A lack of fit between human, organizational, and technological aspects hinders technology adoption and limits its potential (Xu et al., 2022).

The HOT-fit theory, combining the "DeLone and McLean's IS Success Model" and the "Information Technology organization fit model" for information systems (Yusof et al., 2008a, 2008b), aims to enhance innovation adoption success. Ahmadi et al. (2015) explained that the HOT-fit model is flexible, applicable in diverse contexts, accommodating various stakeholders' perspectives, and allowing different ways of evaluating systems' life cycles. The HOT-fit model considers human, organizational, and technological dimensions equally, incorporating characteristics and bi-party relationships within these dimensions. Individual characteristics influence the HOT fit through bi-party fits like HO fit, HT fit, and OT fit.

Yadegaridehkordi et al. (2020) highlighted similarities and distinctions between TOE and HOT-fit. While TOE addresses human perspectives, it lacks coverage of human factors, which HOT-fit encompasses. TOE is adept at examining technology adoption within a company

by incorporating environmental perspectives (Oliveira & Martins, 2011). To address theoretical gaps, integrating these two models provides a comprehensive framework considering all relevant perspectives. Nilashi (2016) noted that this integrated approach is increasingly used for enhanced decision-making in organizations. Recognizing the complexity of technology adoption, Sun et al. (2018) acknowledged that one theory may not suffice. Thus, integrating TOE and HOT-fit serves as a robust base for framework development in this research, aiming to address the high failure rate of digital transformation adoption in Malaysian manufacturing firms, where culture is a top challenge linked to transforming individuals through digital technologies,

Research Hypotheses

Cost and Digital Transformation

Albukhitan (2020) underscores the significant financial commitment required to guide a manufacturing facility through the digital transformation journey. While the benefits, both immediate and long-term, are extensive, it is crucial not to overlook each company's unique revenue and cost structures. Financial constraints compel senior management to exercise caution in their capital allocation and investment decisions. Consequently, only organizations with ample financial resources perceive embarking on the digital transformation journey as feasible (Wong et al., 2019).

Industry reports highlight that costs associated with implementing Smart Manufacturing Information Digital Technology vary due to a mix of fixed and variable factors. These include expenses related to dismantling existing physical infrastructure, acquiring new digital hardware, software applications, and modules, implementing robust security measures, obtaining licenses, seeking external expertise, conducting in-house training, integrating new systems, and managing ongoing maintenance (Ghobakhloo & Hong, 2014). Investments in emerging digital technologies like the Industrial Internet of Things or intelligent ERP are acknowledged for their inherent risks and complexities (Alasdair Gilchrist, 2016). Navigating these advanced technologies demands substantial upfront investments covering hardware, software, licensing, and indirect implementation costs (Albukhitan, 2020). In light of these financial considerations, CEOs and owner-managers may hesitate to invest in manufacturing digitization or digitalization if they perceive the journey as financially unviable. Therefore, the hypothesis is proposed:

H1: Cost has a negative impact on Digital Transformation adoption.

Organizational Agility and Digital Transformation

Ahmad et al (2021), highlight the importance of organizational agility in this digital era, which enables rapid response to market changes and adoption of new technologies. Agility, defined by Sambamurthy et al (2003), as the ability to seize digital market opportunities quickly, is critical for maintaining competitiveness. It allows companies to overhaul processes by introducing new procedures and acquiring innovative resources (Ferraris et al., 2022). Žitkienė and Deksnys (2018) describe organizational agility (OA) as the capacity to detect and respond swiftly to environmental changes, gaining a competitive edge.

Gupta et al (2020), suggest that digital transformation (DT) can also be driven by external pressures from customers, competitors, or regulatory bodies, compelling organizations to adopt technology (Bresciani et al., 2021). Regardless of the pressure source,

proper organizational adaptation is crucial for successful digital transformation (Teichert, 2019). Manufacturing firms, especially in competitive environments, must transition from traditional practices to more agile methods to facilitate effective digital transformation. Hence, it is hypothesized that organizational agility has a positive relationship with digital transformation adoption.

H2: Organizational Agility has a positive relationship with digital transformation adoption

Competitive Pressure and Digital Transformation

Government support and competitive pressures play pivotal roles in influencing manufacturing firms' decisions to adopt digital technologies in the Industry 4.0 era (Ghobakhloo & Iranmanesh, 2021). Competitive pressure specifically refers to the risk of losing market share and customers, a critical concern in today's dynamic business environments where firms must continuously innovate to stay ahead (Yang et al., 2021). Digital transformation is increasingly recognized as essential for enhancing competitive positioning and organizational capabilities (AlNuaimi et al., 2022). This trend is particularly pronounced in industries characterized by high rates of innovation and intense competitive challenges, where digital transformation serves not only as a strategic imperative but also as a means to ensure corporate survivability and resilience (Albukhitan, 2020).

Research underscores that merely investing in basic information technology may not confer sustainable competitive advantage (Ghobakhloo & Hong, 2014). In Malaysia, the manufacturing sector faces mounting competitive pressures both domestically and internationally, prompting organizations to adopt new management techniques and digital technologies to address these challenges effectively. As a result, competitive pressures significantly influence the adoption of digital technologies among manufacturing firms, indicating that those operating in fiercely competitive environments are more likely to embrace digital transformation initiatives proactively to outperform their competitors (Müller et al., 2019).

Therefore, it is hypothesized that competitive pressure positively influences digital transformation efforts in Malaysian manufacturing firms, underscoring the strategic role of digital technologies in responding to competitive dynamics and enhancing organizational resilience in rapidly evolving markets.

H3: Competitive Pressure positively influences Digital Transformation

Digital Transformational Leadership and Digital Transformation

Examining the human dimension of digital transformation (DT), leadership is critical in driving digital initiatives. McGrath and McManus (2020), highlight that modern business leaders often hastily invest in large-scale digital transformation projects with high expectations. However, this impulsive approach frequently leads to costly failures, management turnovers, employee layoffs, and scaling back digital efforts to pilot stages (Siebel, 2019). This issue arises from the gap between digital transformation rhetoric and its execution, widening the strategy-execution gap (Li, 2020).

Effective digital transformation leadership involves more than technological understanding; it requires inspiring and guiding teams through complex changes (Alnuaimi et al., 2022). Leaders play a critical role in both strategy and execution, influencing overall

organizational success. Successful digital transformation depends not just on acquiring new technology but significantly on leaders' dedication and proactive involvement. Bouncken and Barwinski (2021) emphasize that owners and senior management shape the organizational environment, crucial for maximizing digital transformation benefits. In manufacturing, DT often entails a comprehensive shift in the operational model, requiring skilled leadership and strong commitment. Benlian and Haffke (2016) stress that firms undergoing transformation need effective leaders to coordinate diverse procedures and ensure successful implementation.

H4: Digital Transformational Leadership has a positive relationship with Digital Transformation.

Theoretical Framework

Based on the TOE and HOT-fit models, this study aims to introduce a comprehensive four-dimensional model that incorporates perspectives on "human," "organization," "technology," and "environment." By reviewing extensive literature, this research identifies pivotal factors consistently impacting the success of digital transformation across each dimension. This multidimensional framework seeks to provide a nuanced and holistic understanding of the factors influencing digital transformation outcomes, emphasizing technological advancements, environmental contexts, organizational capabilities, and human factors within Malaysian manufacturing firms.

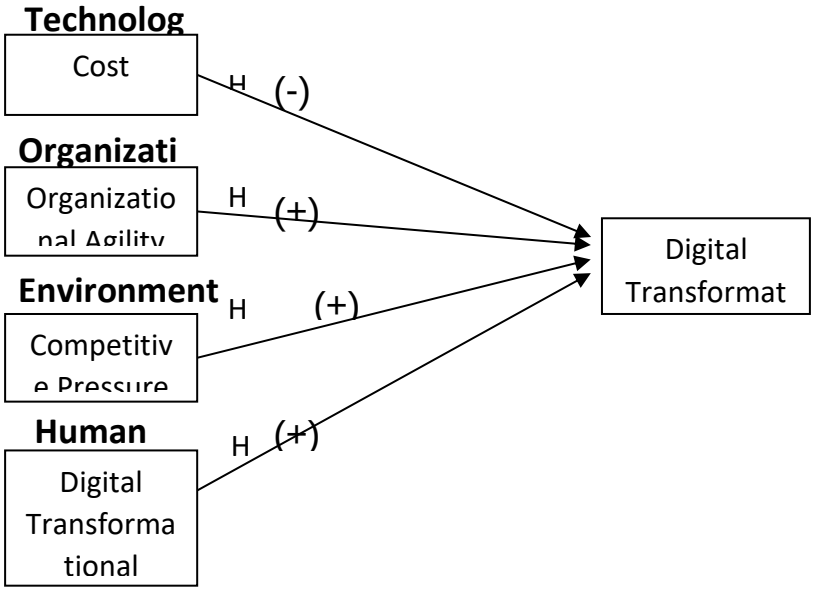

Figure 1: Proposed Theoretical Framework

Research Gaps

Despite the growing interest and investments in digital transformation (DT) within the manufacturing sector, several critical gaps persist in the current literature. First and foremost, while existing studies provide valuable insights into the factors influencing DT adoption, there remains a lack of comprehensive frameworks tailored specifically to the Malaysian manufacturing context. Many studies focus predominantly on Western contexts or generalize findings across diverse industries without adequately accounting for the unique challenges

and opportunities specific to Malaysia's regulatory environment, cultural diversity, and industry structure (Favoretto et al., 2021).

Furthermore, while some research has examined the technological aspects of DT, such as the adoption of AI, IoT, and big data analytics, there is limited empirical evidence on how these technologies integrate with organizational processes and human factors within Malaysian manufacturing firms. The TOE and HOT-fit models offer valuable theoretical frameworks, yet empirical validation within the Malaysian context is sparse, particularly concerning their applicability and effectiveness in predicting DT outcomes (Ghobakhloo & Iranmanesh, 2021). The need for empirical validation is crucial, such as longitudinal studies to track digital transformation adoption over time, or case studies that offer deep dives into the integration challenges of specific technologies like AI or IoT within Malaysian firms.

Moreover, the literature often overlooks the nuanced interplay between external pressures, such as regulatory requirements and market dynamics, and internal organizational capabilities in shaping DT strategies and outcomes. Understanding these dynamics is crucial for formulating effective policies and strategies that support sustainable DT initiatives tailored to Malaysia's unique economic landscape and industrial ecosystem (Albukhitan, 2020).

Lastly, the evolving nature of digital technologies and their rapid advancement necessitate ongoing research that remains current and responsive to emerging trends and disruptions. Continuous monitoring and adaptation of DT strategies are essential to ensure their relevance and effectiveness amidst evolving technological landscapes and global market shifts.

Addressing these gaps requires a multidisciplinary approach that integrates insights from technology management, organizational behavior, economics, and policy studies. By bridging these research divides, this study aims to contribute novel perspectives and practical recommendations that can inform policymakers, industry practitioners, and academic researchers striving to foster sustainable digital transformation in the Malaysian manufacturing sector.

Method

Research Design

This study adopts a quantitative research design, utilizing a cross-sectional survey methodology to collect data from Malaysian manufacturing firms. The research framework is based on the Technology-Organization-Environment (TOE) framework and the Human-Organization-Technology fit (HOT-fit) model to investigate the factors influencing digital transformation adoption. The study aims to test predefined hypotheses derived from these models (Tornatzky & Fleischer, 1990; Yusof & Paul, 2018).

Population and Sampling

The population for this study comprises medium and large manufacturing firms in Malaysia. These firms were selected because they are more likely to have the resources and infrastructure required for digital transformation initiatives. A purposive sampling technique was employed to ensure that only firms with some level of digital transformation adoption were included. This was verified through a preliminary screening question in the survey (Kuo

& Smith, 2018). Purposive sampling allows for a deeper understanding of existing digital transformation strategies and challenges within firms that are not merely theoretical adopters but have practical experiences and insights

Data Collection

Data were collected through an online questionnaire distributed via email. The questionnaire was designed to measure various constructs related to the TOE framework and the HOT-fit model, including technological readiness, organizational readiness, environmental pressures, human factors, and the extent of digital transformation adoption. The constructs were adopted and adapted from existing validated scales from previous study and are all 5 points likert-scale. A pre-test of the questionnaire was conducted with a small sample of industry experts and academics to ensure clarity and validity. The final questionnaire was then distributed to the targeted respondents, with follow-up reminders sent to increase the response rate (Gangwar et al., 2015).

Data Preparation

Before analysis, the collected data underwent a rigorous preparation process. This included data cleaning to identify and correct errors, handling missing values, and ensuring the data met the necessary assumptions for statistical analysis. Missing values were managed using mean imputation for individual items with less than 5% missing data. For items with more substantial missing data, pairwise deletion was applied. Outliers and inconsistencies were identified and addressed to ensure the integrity of the data (Hung et al., 2020).

Data Error

Data errors were identified through a series of checks and validations. These included range checks to ensure that all responses fell within expected limits, consistency checks to detect contradictions in responses, and logical checks to verify the coherence of related items. Where errors were detected, they were corrected based on logical inference or, if necessary, through follow-up with the respondents (Raut et al., 2019).

Missing Values

Missing values were addressed through a systematic approach. For items with minor missing data (less than 5%), mean imputation was used, where the missing values were replaced with the mean of the observed values for that item. For items with more significant missing data, pairwise deletion was employed to maximize the use of available data without introducing bias. This approach helped maintain the robustness and reliability of the dataset (Mohtaramzadeh et al., 2018).

Statistical Data Analysis

The data were analyzed using Structural Equation Modeling (SEM) with Partial Least Squares (PLS-SEM) as the primary analytical technique. PLS-SEM is chosen due to its ability to handle complex models and its robustness in dealing with small sample sizes and non-normal data distributions. The analysis was conducted in two main stages: measurement model assessment and structural model assessment (Hair, 2017).

Exploratory Data Analysis

Exploratory Data Analysis (EDA) was performed to understand the basic characteristics of the data. This included descriptive statistics, such as means, standard deviations, and frequency distributions, as well as visualizations like histograms and box plots to identify patterns and anomalies in the data. EDA provided a foundation for more advanced statistical analyses by revealing underlying trends and relationships within the dataset (Heavin & Power, 2018). By conducting EDA, it would reveal and provide a holistic view on the relationship between the independent variables and the dependent variable, providing valuable insights to researchers and practitioners and ultimately filling the research gaps as discussed in earlier section.

Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was conducted to identify the underlying structure of the measurement items and to confirm the validity of the constructs. EFA helped in reducing the number of variables and detecting the underlying patterns in the data. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to verify the suitability of the data for factor analysis. Principal component analysis with varimax rotation was employed to extract and interpret the factors (Bresciani et al., 2021).

Structural Equation Modeling Applications versus MRA

The study used Structural Equation Modeling (SEM) to test the hypothesized relationships between the constructs, as opposed to Multiple Regression Analysis (MRA). SEM offers several advantages over MRA, including the ability to test multiple relationships simultaneously and to account for measurement errors. The use of SEM allowed for a more comprehensive examination of the complex interdependencies among the technological, organizational, environmental, and human factors influencing digital transformation adoption (Lichtenthaler, 2020).

Expected Findings

This study aimed to explore the factors influencing digital transformation adoption in Malaysian manufacturing firms using the Technology-Organization-Environment (TOE) framework and the Human-Organization-Technology fit (HOT-fit) model. The data collection will involve around 120 respondents and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The analysis shall yield several significant findings that provide insights into the drivers and barriers of digital transformation in this context.

Cost and Digital Transformation

The analysis shall reveal that a company that is more cash rich and bigger in size, which includes the availability and quality of IT infrastructure, significantly impacts digital transformation adoption. Advancement in IT with the drop in investment cost will also be more likely to encourage the adoption of digital transformation initiatives. This finding aligns with previous studies that emphasize the importance of technological readiness in facilitating digital adoption (Wong et al., 2019; Ghobakhloo & Hong, 2014).

Organizational Agility and Digital Transformation

Organizational readiness, including factors such as organizational agility, shall be found to be a critical determinant of digital transformation. Firms with strong adaptive capability and speed to change shall foster innovation and flexibility positively influenced the adoption process. These findings corroborate the existing literature on the role of organizational factors in digital transformation (Bresciani et al., 2021; Lichtenthaler, 2020).

Competitive Pressure and Digital Transformation

Environmental pressures, such as competition, regulatory requirements, and customer demands, also significantly impacted digital transformation adoption. Firms facing intense competitive pressure and stringent regulatory requirements were more likely to adopt digital technologies to maintain their market position and comply with regulations. Customer demand for digital services and products further motivated firms to embark on digital transformation. This supports the notion that external pressures can drive digital innovation (Raut et al., 2019; Saarikko et al., 2020).

Digital Transformational Leadership and Digital Transformation

Human factors, as outlined in the HOT-fit model, played a crucial role in digital transformation. A leader that is supportive and proactive in using digital technologies were significant predictors of successful digital adoption. Training and development programs that enhance digital competencies were found to be essential for facilitating digital transformation and this has to be led by leaders with digital transformational capability. The findings highlight the importance of investing in human capital to support technological changes (Heavin & Power, 2018; Yusof & Paul, 2018).

Discussion on Expected Findings

This study provides valuable insights into the determinants of digital transformation adoption in Malaysian manufacturing firms, utilizing the Technology-Organization-Environment (TOE) framework and the Human-Organization-Technology fit (HOT-fit) model. The findings elucidate several key factors that influence digital transformation, each contributing uniquely to the overall process.

Cost and Digital Transformation

The study highlights that financial resources and company size are critical for digital transformation. Firms with more financial resources are better equipped to invest in advanced IT infrastructure and emerging technologies. This finding aligns with the literature, emphasizing that technological readiness, coupled with reduced investment costs, facilitates digital adoption (Wong et al., 2019; Ghobakhloo & Hong, 2014). Practically, this suggests that companies should strategically plan their budgets to allocate sufficient funds for digital initiatives. Conducting regular cost-benefit analyses will help assess the financial viability of digital initiatives, making it easier to justify investments. Moreover, firms should explore financial incentives, such as government grants or tax breaks, to alleviate the cost burden associated with digital transformation.

Organizational Agility and Digital Transformation

Organizational agility stands out as a vital factor, with agile firms being more capable of innovating and adapting to changes. This aligns with existing research that highlights the

importance of flexibility and swift responsiveness in digital transformation (Bresciani et al., 2021; Lichtenthaler, 2020). Organizations should thus foster an agile culture, encouraging adaptability and continuous learning to support digital transformation efforts. Implementing training programs that enhance employees' ability to adapt quickly to change will further support this goal. Adopting agile project management methodologies such as Scrum, Kanban and Kaizen can also enhance responsiveness, allowing organizations to iteratively develop and refine digital initiatives, thereby increasing their chances of success.

Competitive Pressure and Digital Transformation

External pressures, including competitive dynamics, regulatory demands, and customer expectations, significantly drive digital transformation. Firms under intense competitive pressure and stringent regulatory environments are more likely to adopt digital technologies. This finding supports the idea that external forces can catalyze digital innovation (Raut et al., 2019; Saarikko et al., 2020). For policymakers, this indicates the importance of creating a regulatory framework that both encourages digital adoption and ensures competitive fairness. Firms should engage in competitive benchmarking to identify industry standards and gaps in their own digital strategies. Proactively aligning digital initiatives with regulatory requirements is essential to avoid compliance issues, and developing a customer-centric digital strategy will ensure that investments in digital tools and platforms meet evolving customer needs. This approach will help firms stay competitive and maintain their market position.

Digital Transformational Leadership and Digital Transformation

Human factors, particularly leadership support and employee digital competencies, are crucial for successful digital transformation. Proactive and supportive leadership, coupled with effective training programs, can significantly enhance digital adoption (Heavin & Power, 2018; Yusof & Paul, 2018). Companies should invest in leadership development and continuous upskilling of their workforce to navigate digital changes effectively. Continuous training and development programs for employees are also necessary to enhance digital skills across the organization. By fostering an environment that encourages experimentation with new technologies, firms can build digital self-efficacy, ensuring that employees feel confident in adopting and using new tools effectively.

Theoretical and Practical Implications

The study validates the TOE and HOT-fit models in the context of Malaysian manufacturing, demonstrating their applicability in explaining digital transformation. The robust measurement instruments confirmed through Exploratory Factor Analysis (EFA) and Partial Least Squares Structural Equation Modeling (PLS-SEM) provide a solid foundation for future research. While most findings aligned with the TOE and HOT-fit models, some unexpected results emerged. Competitive pressure, anticipated to be a significant driver of digital transformation, was less influential than expected. This suggests that Malaysian manufacturing firms may not perceive competition as intensely as their global counterparts or prioritize other factors, such as cost and organizational agility. Additionally, digital self-efficacy showed a stronger influence than predicted, indicating that individuals' confidence in their digital skills is crucial for successful transformation, perhaps even more so than external factors like government support. These discrepancies highlight the unique context of

Malaysian manufacturing firms and the importance of local dynamics when applying broad theoretical models.

Practically, the findings offer a roadmap for firms embarking on digital transformation. Ensuring technological and organizational readiness, fostering a culture of innovation, and responding to external pressures are essential steps. For policymakers, supporting digital infrastructure development and providing incentives for digital adoption can accelerate the digital transformation process. A long-term perspective is essential for strategic planning and policy formulation in digital transformation. The study emphasizes the need for manufacturing firms to build resilient, adaptable structures that can evolve with technological advancements. This involves investing not only in current technologies but also in continuous learning to enhance digital skills across the organization. For policymakers, this perspective should guide the creation of a supportive ecosystem that fosters sustained innovation, such as providing incentives for R&D and ensuring flexible regulatory frameworks. A forward-looking approach ensures that digital transformation initiatives meet present demands while positioning the industry for future success.

Future Research Directions

Future research should explore the interplay between these factors in different contexts and industries to generalize the findings. Additionally, longitudinal studies could provide deeper insights into the long-term impacts of digital transformation initiatives. Investigating the role of emerging technologies, such as AI and IoT, in greater detail could also uncover new dimensions of digital transformation.

Conclusion

This study provides a comprehensive examination of the factors influencing digital transformation adoption in Malaysian manufacturing firms, leveraging the Technology-Organization-Environment (TOE) framework and the Human-Organization-Technology fit (HOT-fit) model. The findings underscore the multifaceted nature of digital transformation, highlighting the significant roles of costs, organizational agility, environmental pressures, and digital transformational leadership.

Financially robust firms with advanced IT infrastructure are better positioned to undertake digital transformation, confirming the importance of cost management. Organizational agility emerged as a critical determinant, with adaptable and innovative firms more likely to succeed in digital initiatives. Competitive pressures drive firms towards digital adoption, emphasizing the external catalysts for digital innovation. Human factors, particularly digital transformational leadership is crucial for successful transformation, highlighting the need for continuous investment in human capital.

The study validates the applicability of the TOE and HOT-fit models in the Malaysian manufacturing context, providing a robust theoretical foundation for understanding digital transformation. The practical implications suggest that firms should ensure technological and organizational readiness, foster a culture of innovation, and respond proactively to external pressures. For policymakers, creating a supportive regulatory environment and providing incentives for digital investments are key to accelerating digital transformation.

In conclusion, this study offers actionable insights for both practitioners and policymakers, emphasizing the need for a comprehensive and integrated approach to digital transformation. Limitations of the study, such as its cross-sectional design and focus on Malaysian manufacturing firms, suggest avenues for future research. Longitudinal studies could explore the temporal dynamics of digital transformation, while comparative studies across different sectors and regions could enhance the generalizability of the findings. Overall, this research contributes to both academic understanding and practical applications of digital transformation, guiding organizations and policymakers in navigating the evolving digital landscape effectively.

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