

Original Article

# Factors Affecting Industry 4.0 Readiness in Manufacturing Firms: Evidence from Vietnam

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**Abstract:** The research shed light on the key enabling factors towards manufacturing readiness for Industry 4.0. The study adopted variables' measures from prior research and designed a survey for manufacturing firms. 343 valid responses were conducted using Structural Equation Modeling (SEM) to assess the relationships of the hypothesized variables. The results of the study reveal the positive influence of Smart Technology, Market factors, Organizational capabilities, Innovation capacity, Institutional support, Integrated Supply chain, and Perceived benefits on Industry 4.0 Readiness of Vietnamese manufacturing enterprises. Industry 4.0 is reshaping manufacturing enterprises through digital integration, smart systems, and real-time connectivity, making organizational readiness a critical prerequisite for successful transformation. However, there remain constraints in technological infrastructure, strategic alignment, and operational capability preventing the 4.0 implementation. Therefore, examining the key determinants of Industry 4.0 readiness in manufacturing enterprises is essential to support effective digital transformation and sustainable competitiveness.

**Keywords:** Industry 4.0, Industry 4.0 Readiness, Manufacturing Firm.

## I. INTRODUCTION

Industry 4.0 represents a fundamental transformation of industrial production systems driven by the integration of cyber-physical systems, the Internet of Things (IoT), and digitally interconnected value chains (Lasi et al., 2014). Unlike previous industrial revolutions characterized primarily by mechanization and automation, Industry 4.0 emphasizes intelligent networking, real-time data exchange, and system-wide integration across physical and digital domains (Kagermann, 2014). More broadly, it illustrates how digital, physical, and biological technologies are coming together to change not just manufacturing procedures but also international economic and social structures (Schwab, 2016).

Four fundamental design principles interconnection, information transparency, technical support, and decentralised decision-making form the conceptual foundation of Industry 4.0 in manufacturing settings (Hermann et al., 2016). These ideas make it possible for smart factories to have seamless communication between machines, systems, and people, which improves operational coordination and production flexibility. Empirical and industry reports further suggest that digital transformation initiatives associated with Industry 4.0 can improve productivity, operational efficiency, and manufacturing flexibility (Frank et al., 2019; Rübmann et al., 2015).

Even though certain advantages might be present, the ability of manufacturing organizations to use Industry 4.0 technologies differs significantly. Big multinationals tend to have developed technological systems, funds, and talented human resources to assist in the digital change. In contrast, small and medium - sized enterprises (SMEs) frequently encounter barriers such as limited investment capacity, insufficient digital expertise, and organizational resistance to change (Mittal et al., 2018; Sommer, 2015). These disparities highlight the importance of examining Industry 4.0 readiness prior to full-scale technology implementation.

Industry 4.0 readiness is the extent to which a particular organization is ready to adopt and use digital technologies in its favor (Schumacher et al., 2016). Instead of evaluating the adoption outcomes, readiness is aimed at identifying preconditions that facilitate successful digital transformation. According to the available sources, readiness is inclusive of technological infrastructure, organizational strategy, integration of processes, and competencies of the workforce (Schumacher et al., 2016; Vaidya et al., 2018).

Some internal organizational variables have been described as crucial predictors of readiness for digital transformation. Management support is a key aspect in defining the strategic direction, resource allocation, and the creation of an environment that supports innovation (Ramdani et al., 2009). Technological capability - the presence of IT infrastructure, system integration capacity - directly affects the appropriateness of a company that introduces the latest digital solutions (Xu et al., 2018). The

ability to integrate new technologies into the production systems depends on operational capabilities, including the standardization of processes and their flexibility (Frank et al., 2019).

In addition to internal aspects, organizational preparedness is determined by environmental factors. Digital transformation initiatives can also be either expedited or slowed by the competitive pressure, customer expectations, and regulatory policies (Tortorella & Fettermann, 2018). Public support and policies at the national level that lead to the adoption of Industry 4.0 are proven to have a positive impact on the preparedness of firms, in particular, SMEs (Ruessemann et al., 2015).

In spite of the valuable results of the previous studies, there are still some gaps. First, most research focuses on the results of technology adoption and not preparedness as a pre-implementation phase. Second, very few integrated models (that analyse several dimensions of organizational capability at a time) exist. Third, the emerging economies have rather limited empirical evidence, even though the structure of resource availability and institutional support is different (Frank et al., 2019).

Accordingly, this study aims to investigate the key factors affecting the Industry 4.0 readiness of manufacturing firms by developing a comprehensive research model. By conceptualizing readiness as a multidimensional construct and empirically testing its determinants, this research seeks to provide both theoretical advancement and practical guidance for managers and policymakers preparing for digital transformation.

## II. LITERATURE REVIEW

### A) Industry 4.0

Industry 4.0 will be the fourth industrial revolution, which will be a significant change in the traditional approach of automation towards data-driven, intelligent, and connected production systems. In the last ten years, Industry 4.0 has been transformed into a paradigm of global transformation and no longer a national strategic program, but the redefinition of the systems of manufacturing and the competitiveness of industries. Kagermann and Wahlster (2022) state that Industry 4.0 does not represent only a technological trend but a systemic change that combines cyber-physical systems with organizational and system-level coordination. Although the initial industrial revolution was marked by the mechanization with the use of steam, the second with the introduction of electricity and mass production, and the third with the introduction of information technologies and computers as the basis of automation, the fourth is defined by the ability to introduce digital intelligence into physical production facilities (Hoa and Dong, 2019).

Industry 4.0 is based on Cyber - Physical Systems (CPS), the Industrial Internet of Things (IIoT), cloud computing, artificial intelligence, big data statistics, and better robotics at its technological core (Xu et al., 2018). These technologies allow machines, sensors, and products to communicate in real time and build highly adaptable decentralized production spaces. Industry 4.0 technologies, as opposed to the traditional automation systems, which tend to be a solitary silo, enable ongoing data exchange between production and supply chains, as well as service networks. Frank et al. (2019) note that the Industry 4.0 technologies adopted by firms are usually done in a group, not individually, but through integration of digital connectivity, data analytics, and automation to gain greater performance benefits. The combined implementation also improves predictive maintenance, production planning accuracy, and resource optimization.

One of the characteristic features of Industry 4.0 is the creation of smart factories. Such environments have digitally integrated production systems that can self-monitor, self-diagnose, and, to some extent, even self-optimize. It is possible to have decentralized decision-making where machines and systems process real-time data to modify production information automatically. Moreover, digital simulation and digital twins allow businesses to run the processes in the virtual world and thus prior to physical implementation to minimize operational risks and speed up the innovation cycle (Xu et al., 2018). The change also favors mass customization, where the manufacturing companies can create unique commodities at almost the level of mass production.

In addition to operational efficiency, Industry 4.0 transforms business models and competitive forces. Buer et al. (2018) posit that implementing the Industry 4.0 technologies in combination with lean manufacturing processes contributes to the improvement of transparency and waste reduction, which increases operational excellence. Besides, related products create unending data flows that can be used in predictive services, remote monitoring, and outcome-driven business models. Value creation can be extended to service-based and data-driven products in addition to ownership of products. (Kagermann & Wahlster, 2022) stress that this change not only touches on the individual companies, but also on the whole industrial ecosystem, which requires institutional space and collaboration at the level of supply chains.

Industry 4.0 then must be viewed as a multidimensional change that encompasses elements of technological innovation, organizational change, and strategic realignment. Its proper adoption requires not only digital infrastructure but also flexible leadership, human resources, and inter-organizational alignment. These consequences emphasize the role of evaluation of organizational readiness in implementing extensive digital transformation undertakings.

## **B) Industry 4.0 Readiness**

Industry 4.0 preparedness describes the potential ability of an organization to start, deploy, and maintain digital transformation in line with Industry 4.0 values. It is not just that of technological preparedness but that of strategic coherence, organizational culture, workforce competencies, and process integration. Schumacher et al. (2016) use the concept of Industry 4.0 readiness as a maturity-based construct and suggest a multidimensional assessment model to measure strategic orientation, smart operations, digital services, and employee capabilities. This position acknowledges preparation as a developmental process and not a dichotomous position.

The maturity model developed by Schumacher et al. (2016) suggests that firms move through distinct stages, from initial awareness and pilot implementation to full digital integration. Each stage requires increasing levels of technological sophistication and organizational coordination. Similarly, it is emphasized that readiness depends on the alignment between digital strategy, process integration, and technological infrastructure. Without strategic alignment, isolated technology investments may lead to fragmented systems and suboptimal performance outcomes (Akdil et al., 2017).

Technological readiness forms the structural backbone of Industry 4.0 transformation. Frank et al. (2019) demonstrate that manufacturing firms exhibit varying implementation patterns depending on their digital maturity levels. Firms that have interoperable IT services, automation systems, and real-time analytics are better placed to exploit digital opportunities. Nevertheless, technological infrastructure is not enough. According to Sony (2020), the determinant of readiness is a leadership commitment and change management capability. Good leadership creates a definite digital vision, resource distribution, and employee engagement. In the meantime, the practice of change management decreases resistance in the organization and promotes a cultural adjustment.

Readiness of human resources is also core. Digital literacy, analytical skills, interdisciplinary teamwork, and the possibility to work with intelligent systems are the requirements of Industry 4.0. To enhance absorptive capacity, organizations should develop learning mechanisms that are continuous. In particular, Moeuf et al. (2018) emphasize that SMEs have their own readiness issues because of a lack of financial resources, insufficient digital skills, and a shortage of resources. Consequently, readiness assessment is even more critical for SMEs to focus on their investments and risk reduction.

In addition, Industry 4.0 preparedness can be considered a diagnostic and strategic planning tool. The ability to recognize the capability gaps will allow firms to develop gradual change plans in line with the long-term strategic plans. The assessment of readiness also makes the policy makers aware that there are areas that the institution needs to support, particularly those SMEs that are operating in a resource-limited environment. Industry 4.0 preparation is, therefore, one of the underlying circumstances that define the extent, pace, and long-term viability of digital transformation.

## **C) Factors Influencing Industry 4.0 Readiness**

The combination of technological, organizational, and environmental determinants determines Industry 4.0 preparedness. This paper takes advantage of previous studies and defines seven major influencing variables, namely Smart Technology (ST), Market Factors (MF), Integrated Supply Chain (ISC), Institutional Support (IS), Perceived Benefits (PB), Organizational Capabilities (OC), and Innovation Capacity (IC). These are interdependent factors that not only affect structural preparedness but also strategic commitment.

### **a. Smart Technology**

Smart Technology indicates the extent to which companies embrace and apply new high-tech devices like the Internet of Things, artificial intelligence, big data analytics, and automation technologies (Xu et al., 2018). The technologies allow gathering real-time data, predictive maintenance, and optimization of the processes. As Frank et al. (2019) point out, the greater the level of digital integration, the more successful the operational results of the firm as well as the subsequent strategic flexibility. Nonetheless, Moeuf et al. (2018) believe the high cost of investments, the incompatibility of a legacy system, and a lack of technical skills are common challenges faced by SMEs. Therefore, technological sophistication directly affects preparedness through the presence of the structural capacity, as such, whether firms have the capacity to support digital transformation.

### **b. Market Factors**

Market factors refer to competitive intensity, technological turbulence, and changing customer expectations. In increasingly digitalized markets, firms face pressure to enhance responsiveness, customization, and service integration. Buer et al. (2018) show that combining lean principles with digital technologies strengthens agility and performance. Competitive pressure encourages firms to accelerate digital initiatives in order to maintain market relevance. Therefore, dynamic market conditions act as an external stimulus that compels organizations to enhance Industry 4.0 readiness.

### **c. Integrated Supply Chain**

Integrating the supply chain makes things clearer, easier to work together, and more flexible. Ivanov et al. (2019) show that digital technologies improve supply chain risk analytics and reduce the effects of disruptions. Digitally connected supply chains enable planning, optimising inventory, and coordinating in real time. Companies that are part of integrated digital ecosystems are better able to use Industry 4.0 technologies because they already have ways to share data and work together.

### **d. Institutional Support**

Institutional support encompasses governmental policies, regulatory frameworks, financial incentives, and digital training programs. Akdil et al. (2017) emphasize that national Industry 4.0 initiatives reduce uncertainty and stimulate technology adoption. Institutional support is particularly crucial for SMEs, which often lack sufficient financial and technical resources. Supportive policy environments lower adoption risks and encourage collaborative innovation. Consequently, institutional support positively influences readiness by strengthening confidence and reducing structural barriers.

### **e. Perceived Benefits**

Perceived Benefits show what managers think about the economic and strategic benefits of adopting Industry 4.0. Based on the Unified Theory of Acceptance and Use of Technology, Venkatesh et al. (2012) contend that perceived usefulness profoundly affects behavioural intention. Decision-makers are more likely to invest in digital transformation when they expect it to improve productivity, reduce costs, enhance quality, and gain a competitive edge. So, perceived benefits act as a mental driver that connects environmental pressures and organisational action.

### **f. Organizational Capabilities**

Organisational capabilities include things like leadership commitment, strategic alignment, communication structures, and systems for managing knowledge. Sony (2020) says that leadership and organisational culture are two of the most important things that make Industry 4.0 possible. Companies with effective ways of working together and cultures that encourage learning are more flexible. Organisational capabilities make sure that investments in technology are used to help achieve strategic goals instead of being used on their own. Sharing knowledge in a useful way increases absorptive capacity and helps with ongoing change.

### **g. Innovation Capacity**

Innovation Capacity is the ability to try out, improve, and use new technology solutions. Frank et al. (2019) say that companies that use Industry 4.0 technologies often have a strong focus on research and development (R&D) and work well with people from different departments. The ability to innovate makes things more flexible and helps with custom digital integration strategies. It also makes you more competitive in the long run in tech environments that change quickly. Companies with strong innovation ecosystems are better able to adapt to new technologies and keep up with digital transformation efforts.

In general, being ready for Industry 4.0 comes from the interaction of technological infrastructure, managerial cognition, organisational capabilities, and environmental conditions. Smart technology is the structural backbone, while organisational capabilities and innovation capacity make the company more flexible. Market dynamics and institutional support create pressure and help from the outside, and perceived benefits affect how committed managers are. The interplay among these dimensions ultimately dictates the efficacy and longevity of Industry 4.0 transformation initiatives.

## **III. RESEARCH MODEL AND HYPOTHESES**

### **A) Research Hypotheses**

Smart Technology represents the technological foundation of Industry 4.0, including IoT, cyber-physical systems, cloud computing, big data analytics, and automation (Lasi et al., 2014). The availability and maturity of digital technologies within firms significantly influence their preparedness for digital transformation (Xu et al., 2018). In assessing Industry 4.0 readiness, technological infrastructure and digital maturity are core components of readiness measurement (Frank et al., 2019; Schumacher et al., 2016). Without adequate technological infrastructure, firms face significant constraints in implementing smart manufacturing initiatives (Mittal et al., 2018).

*H1. Smart Technology positively affects Industry 4.0 readiness.*

According to the Technology - Organization - Environment (TOE) framework, environmental pressures such as competition, customer demand, and industry dynamics significantly influence technological readiness (Tornatzky, 1990). Competitive intensity and customer expectations are important drivers for investing in digital transformation (Tortorella & Fettermann, 2018). Empirical evidence also indicates that firms operating in dynamic markets are more likely to adopt Industry 4.0 technologies to maintain competitiveness and improve responsiveness.

*H2. Market factors positively affect Industry 4.0 readiness.*

Organisational Capability includes things like how committed managers are, how available resources are, how flexible the structure is, and how well the digital strategy works. From a Resource-Based View perspective, firm-specific capabilities are essential for sustaining competitive advantage during digital transformation (Barney, 1991). In Industry 4.0, organisational structure and strategy are important parts of readiness, and when leaders are committed, it makes it easier for companies to deal with digital problems (Mittal et al., 2018; Schumacher et al., 2016). Poor management vision and a lack of flexibility in the organization are two big problems that make it hard to change to digital (Sommer, 2015).

*H3. Organizational capability positively affects Industry 4.0 readiness.*

Perceived Benefits are the beliefs that decision-makers have about how well Industry 4.0 works and how it can help them reach their goals. The Unified Theory of Acceptance and Use of Technology (UTAUT) posits that performance expectancy substantially affects technology adoption decisions (Venkatesh et al., 2003). Prior studies indicate that perceived strategic and operational advantages significantly impact digital transformation initiatives within manufacturing enterprises (Ghobakhloo, 2018; Vaidya et al., 2018). Managers are more likely to prepare for Industry 4.0 technologies when they believe these technologies will make their businesses more productive, efficient, and competitive.

*H4. Perceived benefits positively affect Industry 4.0 readiness.*

Institutional Support includes governmental policies, financial incentives, legal frameworks, and digital transformation programs. Institutional theory suggests that regulatory and normative pressures shape organizational behavior (DiMaggio & Powell, 1983). Research indicates that public policies promoting Industry 4.0 significantly enhance firms’ digital preparedness and reduce uncertainty, especially for SMEs (Li et al., 2018; Mittal et al., 2018).

*H5. Institutional support positively affects Industry 4.0 readiness.*

Industry 4.0 emphasizes horizontal and vertical integration across supply chains to enable real-time data sharing, operational transparency, and responsive coordination (Kagermann, 2014). Evidence shows that digitally integrated supply chains enhance responsiveness and resilience, facilitating Industry 4.0 implementation (Ivanov et al., 2014). Supply chain collaboration further supports the deployment of advanced manufacturing systems (Tortorella & Fettermann, 2018). In contrast, a lack of integration presents barriers to smart manufacturing (Mittal et al., 2018).

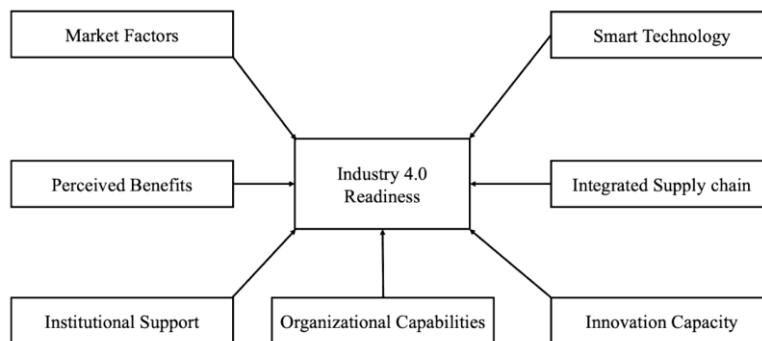
*H6. Supply chain integration positively affects Industry 4.0 readiness.*

Innovation Capability reflects a firm’s ability to generate, adopt, and implement new ideas and technologies. From an RBV perspective, innovation capability is a strategic resource that supports digital transformation (Barney, 1991). Research shows that innovative firms are more proactive in adopting Industry 4.0 technologies (Frank et al., 2019). Moreover, dynamic capability theory suggests that firms with stronger innovation capacity can better reconfigure resources in response to technological change (Teece, 2007).

*H7. Innovation capability positively affects Industry 4.0 readiness.*

**B) Proposed Research Model**

Based on previous studies, the research team inherits and adapts established theoretical foundations to develop a research model that is appropriate for the current study. The proposed research model consists of seven independent variables (Smart Technology, Market Factors, Organizational Capability, Perceived Benefits, Institutional Support, Supply Chain Integration, and Innovation Capability) and one dependent variable (Industry 4.0 Readiness).



**Figure 1. Research Model**

*Source: Research results*

- H1. Smart Technology positively affects Industry 4.0 readiness.
- H2. Market factors positively affect Industry 4.0 readiness.
- H3. Organizational capability positively affects Industry 4.0 readiness.
- H4. Perceived benefits positively affect Industry 4.0 readiness.
- H5. Institutional support positively affects Industry 4.0 readiness.
- H6. Integrated Supply chain positively affects Industry 4.0 readiness.
- H7. Innovation capability positively affects Industry 4.0 readiness.

#### IV. RESEARCH METHODOLOGY

##### A) *Research Design and Data Collection*

This research employs a quantitative methodology, utilising a cross-sectional survey design, to investigate the determinants affecting Industry 4.0 readiness within manufacturing firms in Vietnam. A survey method was chosen due to its capacity to gather standardised data from a substantial number of firms and its extensive use in previous research evaluating Industry 4.0 readiness and maturity at the organisational level (Castelo-Branco et al., 2019; Schumacher et al., 2016). This method lets you look at different aspects of technology, organisations, markets, and institutions all at once in a single analytical framework.

The questionnaire was created using validated measurement scales from earlier research on the readiness of manufacturing companies for Industry 4.0 and digital transformation (Schumacher et al., 2016). The items were carefully changed to fit the Vietnamese business setting while still being consistent with the ideas behind the original theoretical constructs. Before the official data collection, the questionnaire was reviewed to ensure it was clear, relevant, and easy for respondents to understand.

The survey was sent out as a Microsoft Word document directly to manufacturing companies' official email addresses. The people who answered the questions were senior or middle-level managers, heads of technical departments, or digital transformation officers who were well-versed in their companies' production processes and digital projects. Participants were instructed to complete the questionnaire and submit it via email to the research team. Data gathering took place from January 2026 to February 2026. Five hundred manufacturing companies answered the survey. After checking the data to get rid of incomplete and inconsistent answers, 343 questionnaires were found to be valid and kept for further analysis. All participants were apprised of the research objectives, confidentiality guarantees, and the voluntary nature of their participation to ensure compliance with ethical research standards.

##### B) *Measurements*

The research model comprises seven independent variables: Smart Technology, Market Factors, Organisational Capability, Perceived Benefits, Institutional Support, Integrated Supply Chain, and Innovation Capability, alongside one dependent variable, Industry 4.0 Readiness. The measurement scales were developed from recognised Industry 4.0 readiness and maturity models in existing literature (Castelo-Branco et al., 2019; Schumacher et al., 2016), offering a robust theoretical framework for evaluating technological capability, organisational readiness, and environmental support mechanisms in contexts of industrial transformation. A five-point Likert scale, with 1 being "Strongly disagree" and 5 being "Strongly agree," was used to measure all of the constructs. The five-point Likert scale is frequently employed in management and organisational research because of its simplicity, respondent accessibility, and statistical reliability in factor analysis (Hair, 2019).

The reliability and validity of the measurement scales were evaluated according to established protocols in structural equation modelling. The initial assessment of internal consistency reliability employed Cronbach's Alpha, which has a suggested threshold of 0.70 (Hair, 2019). Subsequently, Exploratory Factor Analysis (EFA) was performed utilising SPSS 26.0 to investigate the fundamental factor structure. The Kaiser – Meyer - Olkin (KMO) measure ( $\geq 0.50$ ) and Bartlett's Test of Sphericity ( $p < 0.05$ ) were used to see if the data were good enough for factor analysis. Eigenvalues greater than 1, factor loadings of at least 0.50, and a total variance explained of more than 50% were required to keep factors (Hair, 2019).

Subsequently, Confirmatory Factor Analysis (CFA) was performed using AMOS 20.0 to validate the measurement model. Convergent validity was established when standardized factor loadings were  $\geq 0.50$  (preferably  $\geq 0.70$ ), Average Variance Extracted (AVE) exceeded 0.50, and Composite Reliability (CR) was above 0.70 (Fornell & Larcker, 1981; Hair, 2019). Discriminant validity was confirmed when the square root of AVE for each construct was greater than its correlations with other constructs. Model fit was evaluated using multiple goodness-of-fit indices, including  $CMIN/df \leq 3$ , CFI and TLI  $\geq 0.90$ , RMSEA  $\leq 0.08$ , and SRMR  $\leq 0.08$  (Byrne, 2016; Hair, 2019). Only after the measurement model satisfied these criteria was the structural model tested.

**C) Sampling and Data Analysis**

The target population of this study comprises manufacturing enterprises operating in Vietnam. A purposive sampling technique was employed to ensure that respondents possessed relevant knowledge and experience related to production management or digital transformation initiatives. This approach is appropriate for organizational-level research, where informed managerial perspectives are critical for evaluating technological readiness (Castelo-Branco et al., 2019). The sample size was determined based on the requirements of Covariance-Based Structural Equation Modeling (CB-SEM). According to Hair et al. (2019), SEM studies should include at least 200 observations to ensure stable parameter estimation and reliable results (Hair, 2019). Therefore, with 343 valid responses, the present study exceeds the recommended minimum threshold, confirming that the sample size is adequate to ensure robust parameter estimation and reliable SEM results.

Data analysis was conducted in several stages. First, the dataset was screened for missing values, outliers, and normality assumptions using SPSS 26.0 (Hair, 2019). Descriptive statistics were then used to summarize the sample characteristics. EFA was performed to confirm the factor structure before proceeding to CFA in AMOS 20.0. After establishing the reliability and validity of the measurement model, the structural model was tested using SEM in AMOS 20.0 to examine the relationships between the seven independent variables and Industry 4.0 readiness. Standardized path coefficients and statistical significance levels ( $p < 0.05$ ) were used to evaluate the research hypotheses. The use of CB-SEM via AMOS 20.0 is appropriate for this study because the primary objective is theory testing and assessing overall model fit within a theoretically grounded framework (Hair et al., 2019).

**V. FINDINGS**

**A) Descriptive statistics**

A total of 343 valid responses were selected after the survey. The majority of manufacturing enterprises primarily operate in the sector of Textile and garment manufacturing (15.16%) and Rubber and plastic product manufacturing (14.87%). The information in Table 1 details that most respondents' enterprises were established in the period before 2005 or from 2005 to 2009, with 85 (24.78%) each. As for the location in Vietnam, the greater part of the enterprise has head offices located in the South, with over half, followed by the North (37.02%) and the Central (6.12%).

In addition, regarding business types, Limited Liability Company type accounts for the most with 73.47%, while others have the lowest proportion with only 2.92%. Finally, in terms of enterprise size, the respondents are asked to select the number of employees and the revenue in 2024. The vast number of enterprises consists of 200 - 500 employees and generated around 50 - 300 billion VND in 2024, which could be identified as a medium enterprise.

**Table 1: Demographic Profiles of Manufacturing Enterprises (N=343)**

	Criteria	Frequency	Percentage (%)
Establishment Time	Before 2005	85	24.78
	From 2005 - 2009	85	24.78
	From 2010 - 2014	81	23.62
	From 2015 - 2019	67	19.53
	From 2020 to the present	25	7.29
Head office location	Northern Vietnam	127	37.02
	Central Vietnam	21	6.12
	Southern Vietnam	195	56.85
Business Types	Corporation	66	19.24
	State-owned enterprises	15	4.37
	Limited Liability Company	252	73.47
	Others	10	2.92
Main Business Sector	Food and beverage production and processing	17	4.96
	Pharmaceutical, chemical, and medicinal production	39	11.37
	Textile and garment manufacturing	52	15.16
	Leather manufacturing and related products	29	8.45
	Paper manufacturing and paper products	43	12.54
	Rubber and plastic product manufacturing	51	14.87
	Wood processing and wood products (bamboo, rattan; beds, wardrobes, tables, chairs)	33	9.62
	Manufacturing of electronic products, computers, and optical products	25	7.29
	Electrical equipment manufacturing	15	4.37
	Automobile and other motor vehicle manufacturing; other transport equipment	19	5.54
	Other manufacturing and processing industries	17	4.96
Other industries	3	0.87	

Number of workers	Under 10	30	8.75
	10 - 100	68	19.83
	101 - 200	89	25.95
	201 - 500	138	40.23
	Over 500	18	5.25
Revenue in 2024	Below 3 billion VND	17	4.96
	3 – 50 billion VND	78	22.74
	50 – 200 billion VND	126	36.73
	200 – 300 billion VND	101	29.45
	Above 300 billion VND	21	6.12

Source: Research results

**B) Scale Assessment**

Authors use Cronbach’s Alpha to assess the reliability of scales for variables in the proposed research model. The results show that Cronbach’s Alpha index of all variables ranged from 0.807 to 0.944, which is higher than 0.7; accordingly, scales are considered as highly reliable (Hair, 2010). The data correlations were consistent with the constructed scales and could be used for Exploratory Factor Analysis (EFA).

**Table 2: Reliability Analysis (N = 343)**

Factor	Cronbach’s Alpha	Corrected Item-Total Correlation
Smart Technology (ST)	0.921	0.689 – 0.814
Market Factors (MF)	0.931	0.695 – 0.763
Integrated Supply Chain (ISC)	0.872	0.646 – 0.796
Institutional Support (IS)	0.944	0.734 – 0.804
Perceived Benefits (PB)	0.807	0.695 – 0.814
Organizational Capabilities (OC)	0.898	0.730 – 0.801
Innovation Capacity (IC)	0.877	0.716 – 0.730
Industry 4.0 Readiness (I4R)	0.915	0.685 – 0.801

Source: Research results

To assess the measurement scale accurately, the EFA analysis was conducted using the *Principal Axis Factoring* extraction method and *Promax* rotation. The results of the verification of the validity of the scales by EFA indicated a total variance explained of 63,373% and a KMO coefficient of 0.927. Bartlett’s test of sphericity was significant ( $p < 0.001$ ).

**Table 3: EFA result**

Scale	Rotated Factor Matrix							
	Factor							
	1	2	3	4	5	6	7	8
IS4	0.830							
IS2	0.826							
IS5	0.822							
IS6	0.815							
IS10	0.798							
IS1	0.795							
IS3	0.771							
IS8	0.760							
IS9	0.746							
IS7	0.735							
MF7		0.836						
MF1		0.785						
MF2		0.780						
MF3		0.772						
MF8		0.759						
MF4		0.743						
MF6		0.741						
MF9		0.731						
MF10		0.729						
MF5		0.719						
ST4			0.860					
ST6			0.856					

ST7			0.848					
ST5			0.842					
ST1			0.739					
ST3			0.693					
ST2			0.685					
I4R7				0.852				
I4R1				0.830				
I4R6				0.814				
I4R4				0.767				
I4R5				0.750				
I4R2				0.733				
I4R3				0.651				
PB1					0.896			
PB2					0.872			
PB4					0.810			
PB3					0.777			
PB5					0.668			
OC2						0.892		
OC1						0.837		
OC3						0.808		
OC4						0.762		
IC3							0.842	
IC2							0.803	
IC4							0.788	
IC1							0.772	
ISC1								0.959
ISC2								0.853
ISC4								0.694
ISC3								0.621

**Source:** Research results

The measurement model was satisfactory when Confirmatory Factor Analysis (CFA) was performed. The t-test results for all observed variables demonstrated their significance at the 0.001 level. Moreover,  $\chi^2(1141) = 1856.942$ ;  $\chi^2/df = 1.627 < 2$ ;  $p < 0.01$ ; CFI = 0.949 > 0.9; TLI = 0.945 > 0.9; and RMSEA = 0.039 < 0.05. Additionally, the results showed that all factor loadings ( $\lambda$ ) of the observed variables were greater than 0.5. Therefore, all observed variables were deemed adequate for Structural Equation Modeling (SEM) analysis (Hair, 2010).

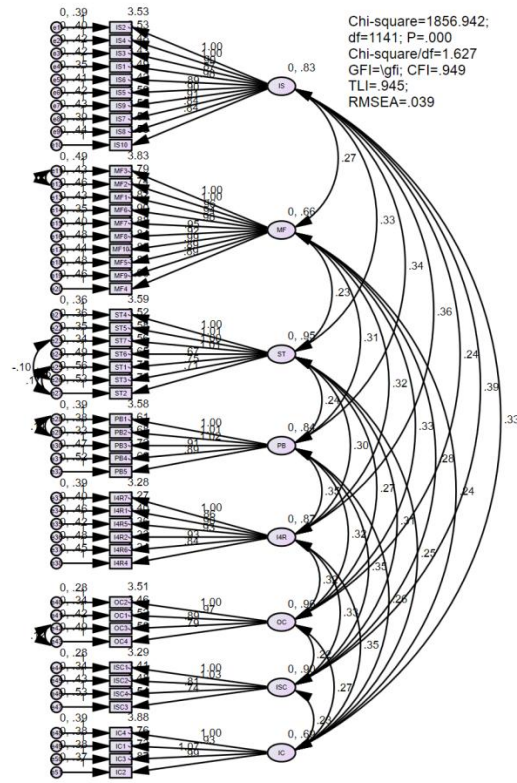


Figure 2. CFA Results

Source: Research results

C) Structural path analysis

The SEM results (Figure 2) suggested that the hypothesized model fit the data well, specifically:  $\chi^2(1202) = 2364.279$ ;  $\chi^2/df = 1.967 < 2$ ;  $p < 0.01$ ;  $GFI = 0.793 > 0.8$ ;  $CFI = 0.919 > 0.9$ ;  $TLI = 0.914 > 0.9$ ; and  $RMSEA = 0.049 < 0.5$  (Hair, 2020).

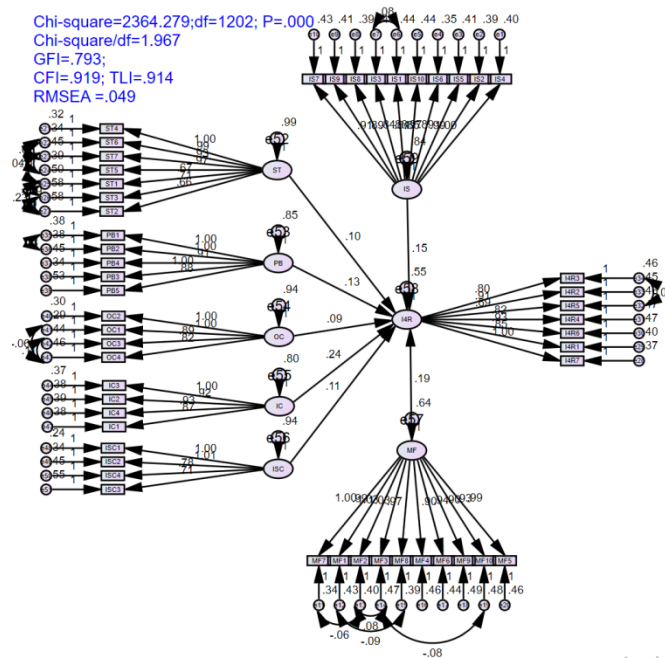


Figure 3. SEM Results

Source: Research results

The test results for the proposed hypotheses are presented in Table 3. All hypothesized interrelationship coefficients are found to be significant. The authors’ findings indicate that seven factors have a positive and direct impact on Industry 4.0 Readiness among manufacturing enterprises. Among them, Innovation Capacity ( $\beta = 0.236$ ;  $p < 0.001$ ) exerts the strongest influence, followed by Market Factors ( $\beta = 0.195$ ;  $p < 0.001$ ), Institutional Support ( $\beta = 0.151$ ;  $p < 0.05$ ), Perceived Benefits ( $\beta = 0.125$ ;  $p < 0.05$ ), Integrated Supply chain ( $\beta = 0.109$ ;  $p < 0.05$ ), Smart Technology ( $\beta = 0.097$ ;  $p < 0.05$ ) and Organizational Capabilities ( $\beta = 0.093$ ;  $p < 0.05$ ).

**Table 4: Hypothesis Testing Results**

Relationships			Standardized regression	S.E	C.R	Sig.	Result
Industry 4.0 Readiness	<--	Organizational Capabilities	0.093	0.043	2.150	0.032	Accepted
Industry 4.0 Readiness	<--	Smart Technology	0.097	0.042	2.329	0.020	Accepted
Industry 4.0 Readiness	<--	Integrated Supply Chain	0.109	0.043	2.508	0.012	Accepted
Industry 4.0 Readiness	<--	Innovation Capacity	0.236	0.049	4.860	***	Accepted
Industry 4.0 Readiness	<--	Perceived Benefits	0.125	0.046	2.744	0.006	Accepted
Industry 4.0 Readiness	<--	Institutional Support	0.151	0.045	3.357	***	Accepted
Industry 4.0 Readiness	<--	Market Factors	0.195	0.052	3.761	***	Accepted

Note:  $N = 343$ , \*\*\* $p < 0.001$ .

Source: Research results

## VI. DISCUSSION AND IMPLICATIONS

### A) Discussion

This study aims to examine the factors affecting Industry 4.0 readiness among manufacturing enterprises in Vietnam. Based on the SEM results, all seven hypothesized relationships are supported, indicating that technological, organizational, cognitive, and environmental factors jointly contribute to Industry 4.0 readiness.

#### a. Innovation Capability Positively Affects Industry 4.0 Readiness.

Among the examined factors, Innovation Capacity exerts the strongest influence on Industry 4.0 readiness ( $\beta = 0.236$ ;  $p < 0.001$ ). This finding suggests that the ability to generate, adopt, and implement new technologies plays a central role in preparing manufacturing firms for digital transformation. The result supports the Resource-Based View and dynamic capability theory, emphasizing that internal capabilities - rather than technology alone - determine strategic readiness. While Industry 4.0 is often perceived as technology-driven, the empirical evidence shows that firms’ innovative capacity has a stronger impact than Smart Technology itself ( $\beta = 0.097$ ). This indicates that possessing digital tools is insufficient without the capability to experiment, learn, and reconfigure resources effectively.

In the context of Vietnamese manufacturing enterprises, many of which are medium-sized, innovation capacity may serve as a critical enabler that compensates for limited financial or technological resources. Firms with strong R&D orientation, cross-functional collaboration, and continuous improvement practices are better positioned to translate digital opportunities into structured readiness.

The findings highlight that Industry 4.0 readiness is fundamentally capability-driven, with innovation capacity functioning as the key engine of transformation.

#### b. Market Factors Positively Affect Industry 4.0 Readiness

The results indicate that Market Factors have a strong and significant positive impact on Industry 4.0 readiness ( $\beta = 0.195$ ;  $p < 0.001$ ), making it the second most influential determinant in the model. This finding highlights the critical role of external competitive pressure and changing customer expectations in driving digital preparedness.

Consistent with the Technology - Organization - Environment (TOE) framework, firms operating in dynamic and highly competitive markets are more likely to accelerate digital transformation initiatives to maintain responsiveness and competitiveness. In sectors such as textiles, plastics, and electronics - prominent in the sample - increasing demand for customization, shorter lead times, and supply chain transparency compels firms to enhance technological and organizational readiness.

The relatively strong coefficient for market factors suggests that Industry 4.0 readiness in Vietnam is not purely internally motivated but is also significantly shaped by environmental pressures. Firms may initiate digital transformation not only for strategic innovation but also as a reactive response to market turbulence and global competition.

This finding reinforces the view that Industry 4.0 readiness is partly market-driven, where external competitive dynamics act as a catalyst for organizational change and digital capability development.

**c. Institutional Support Positively Affects Industry 4.0 Readiness**

The findings show that Institutional Support has a positive and statistically significant effect on Industry 4.0 readiness ( $\beta = 0.151$ ;  $p < 0.001$ ). This result underscores the important role of governmental policies, regulatory frameworks, financial incentives, and digital transformation programs in enhancing firms' preparedness for Industry 4.0.

This outcome is consistent with institutional theory, which suggests that regulatory and normative pressures shape organizational behavior. In emerging economies such as Vietnam, where many manufacturing firms are medium-sized and resource-constrained, institutional support reduces uncertainty and lowers the perceived risks associated with digital investments. Public initiatives, training programs, and financial assistance can therefore act as enabling mechanisms that facilitate digital capability development.

Moreover, the relatively strong coefficient indicates that readiness is not solely determined by internal capabilities or market competition but is also significantly influenced by the broader policy environment. Supportive institutional conditions provide legitimacy and strategic direction, encouraging firms to align with national digital transformation agendas.

The results suggest that institutional support functions as a structural enabler of Industry 4.0 readiness, particularly in developing contexts where external guidance and resource facilitation are essential for accelerating digital transformation.

**d. Perceived Benefits Positively Affect Industry 4.0 Readiness**

The results indicate that Perceived Benefits positively and significantly influence Industry 4.0 readiness ( $\beta = 0.125$ ;  $p = 0.006$ ). This finding highlights the critical role of managerial cognition and performance expectations in shaping digital preparedness.

Consistent with the Unified Theory of Acceptance and Use of Technology (UTAUT), when managers believe that Industry 4.0 technologies can enhance productivity, operational efficiency, product quality, and competitive advantage, they are more likely to commit organizational resources to digital transformation. Readiness, therefore, is not only a structural or environmental condition but also a cognitive and strategic decision-making outcome.

The moderate magnitude of this coefficient suggests that perceived benefits act as a motivational driver that translates external pressures and internal capabilities into concrete preparation efforts. Even when technological infrastructure or institutional support is available, transformation initiatives may not progress without strong managerial belief in the strategic value of Industry 4.0.

The findings emphasize that Industry 4.0 readiness is partly perception-driven, where managerial expectations regarding economic and strategic gains play an essential role in initiating and sustaining digital transformation efforts.

**e. Integrated Supply Chain Positively Affects Industry 4.0 Readiness**

The findings reveal that Integrated Supply Chain has a positive and statistically significant effect on Industry 4.0 readiness ( $\beta = 0.109$ ;  $p = 0.012$ ). This result suggests that firms embedded in digitally connected and collaborative supply chain networks are better positioned to prepare for Industry 4.0 transformation.

Industry 4.0 emphasizes horizontal and vertical integration, enabling real-time data sharing, operational transparency, and coordinated decision-making across supply chain partners. Firms that already maintain integrated planning systems, information-sharing platforms, and collaborative partnerships possess a structural foundation that facilitates the adoption of smart manufacturing technologies.

Although the effect size is moderate, the significance of this factor indicates that readiness extends beyond internal organizational boundaries. Digital transformation in manufacturing increasingly requires ecosystem-level alignment rather than isolated firm-level initiatives. Particularly for Vietnamese manufacturing enterprises operating within global value chains, supply chain integration enhances interoperability, traceability, and responsiveness - key components of Industry 4.0 readiness.

The results suggest that integrated supply chain capability functions as an external operational enabler, strengthening firms' ability to implement Industry 4.0 technologies effectively within interconnected industrial ecosystems.

**f. Smart Technology Positively Affects Industry 4.0 Readiness**

The empirical results show that Smart Technology positively and significantly influences Industry 4.0 readiness ( $\beta = 0.097$ ;  $p = 0.020$ ). This confirms that the availability and maturity of digital technologies - such as IoT, automation systems, cloud computing, and data analytics - constitute an essential structural foundation for digital transformation.

Technological infrastructure enables real-time data collection, process monitoring, and system integration, which are core components of Industry 4.0. Firms equipped with interoperable IT systems and advanced automation tools are structurally better prepared to implement smart manufacturing initiatives. Without such technological foundations, readiness efforts may face substantial operational constraints.

However, the relatively smaller coefficient compared to Innovation Capacity and Market Factors suggests that technology alone is not the dominant driver of readiness. This finding implies that while smart technologies are necessary conditions, they are not sufficient on their own. Effective integration, strategic alignment, and organizational adaptability are equally important to translate technological assets into meaningful digital preparedness.

The results support a balanced perspective: Smart Technology provides the structural backbone of Industry 4.0 readiness, but its effectiveness depends on complementary organizational and environmental capabilities.

#### **g. Organizational Capability Positively Affects Industry 4.0 Readiness**

The findings indicate that Organizational Capability has a positive and statistically significant impact on Industry 4.0 readiness ( $\beta = 0.093$ ;  $p = 0.032$ ). Although the effect size is relatively modest, the result confirms that internal managerial commitment, strategic alignment, and structural flexibility contribute to firms' digital preparedness.

Organizational capability reflects leadership vision, coordination mechanisms, knowledge management, and the ability to mobilize resources toward digital initiatives. Industry 4.0 transformation requires not only technological adoption but also changes in processes, culture, and governance structures. Firms with strong leadership support and adaptive organizational systems are more capable of integrating digital technologies into long-term strategic objectives rather than implementing them in isolation.

The comparatively smaller coefficient suggests that, in the Vietnamese manufacturing context, organizational capability alone may not be the primary trigger of readiness. Instead, it functions as an internal supporting mechanism that enhances the effectiveness of innovation capacity, technological infrastructure, and external pressures.

The results highlight that organizational capability acts as an internal coordination enabler, ensuring that digital transformation efforts are strategically aligned, systematically implemented, and sustainably managed.

### **B) Implications**

Based on the empirical findings, several important implications can be drawn for managers, policymakers, and industry stakeholders in the Vietnamese manufacturing sector.

#### **a. Managerial Implications**

Given that Innovation Capacity is the strongest driver of Industry 4.0 readiness, managers should prioritize building internal innovation ecosystems rather than focusing solely on technology acquisition. This involves strengthening R&D activities, fostering cross-functional collaboration, promoting a culture of experimentation, and embedding continuous learning mechanisms. Digital transformation should be approached as an ongoing innovation journey integrated into long-term competitive strategy, especially in industries facing intense market pressure and rising customer demands.

At the same time, firms should actively leverage Institutional Support by participating in government programs, digital transformation initiatives, and available funding or training schemes to mitigate transformation risks. Clear communication of the strategic and operational benefits of Industry 4.0 is also essential to build organizational commitment and reduce resistance to change.

Although Smart Technology, Integrated Supply Chain, and Organizational Capability show comparatively smaller effects, they remain critical enablers. Firms must ensure IT interoperability, strengthen digital integration with supply chain partners, and align organizational structures with digital strategy. Overall, effective Industry 4.0 readiness requires a balanced approach that combines innovation capability, technological infrastructure, organizational alignment, and responsiveness to external pressures.

#### **b. Policy Implications**

The results show that not only do individual companies' efforts affect Industry 4.0 readiness in emerging economies, but so does the larger institutional environment. So, governments should keep making digital transformation policies stronger by giving small businesses targeted financial incentives, tax breaks, low-interest loans, and clear rules. Putting money into public digital infrastructure is also important to lower barriers to adoption and make things less uncertain.

Because innovation capacity is so important, national strategies should go beyond giving money to build infrastructure and instead actively support ecosystems for innovation. This includes making technology hubs, innovation clusters, university-industry collaboration programs, and R&D support that is specific to manufacturing companies. Policies should

also encourage the integration of digital supply chains by using standardised data-sharing frameworks and digital platforms that can work with each other.

In the end, it will be very important to make sure that the Industry 4.0 transformation is long-lasting and open to everyone by expanding programs for workforce development to improve digital skills, analytical abilities, and change management skills.

### c. Industry-Level Implications

Associations and professional networks can help manufacturing companies get ready for Industry 4.0 faster at the industry level. By creating standardised benchmarking tools, these groups can help businesses systematically figure out how mature their digital systems are and where they need to improve. Industry groups can also help businesses, especially small and medium-sized businesses, learn from successful transformation cases and lower the costs of trying new things by setting up platforms for sharing knowledge, workshops, and best-practice exchanges. Also, encouraging collaborative innovation projects like joint R&D efforts or shared digital infrastructure programs can help everyone learn more and make digital integration stronger across the ecosystem. By working together in this way, people in the same industry can greatly reduce fragmentation and encourage a more inclusive and long-lasting digital transformation.

## VII. LIMITATIONS AND FUTURE RESEARCH

### A) Limitations

Despite its contributions, this study has several limitations. First, the research adopts a cross-sectional survey design, which limits the ability to establish causal relationships and to capture the dynamic evolution of Industry 4.0 readiness over time. Second, the data are derived from self-reported perceptions of managers, potentially introducing common method bias and subjective assessment bias, despite statistical confirmation of reliability and validity. Third, the sample is limited to manufacturing companies in Vietnam, which may make it hard to apply the results to other countries or industries. Finally, the model only looks at direct effects between the suggested variables and doesn't look at possible mediating or moderating relationships. These could give us a better understanding of what makes an industry ready for Industry 4.0.

### B) Future research directions

Subsequent research ought to investigate Industry 4.0 readiness through longitudinal methodologies to document its dynamic progression and its influence on organisational performance over time. Subsequent research may investigate mediating and moderating factors such as digital strategy alignment, organisational size, or corporate culture to enhance the comprehension of the structural pathways that facilitate readiness. Furthermore, cross-national comparative studies and mixed-methodologies that integrate survey data with case studies or objective performance metrics would augment the generalisability and rigour of the results. Adding things like digital leadership, cybersecurity skills, and digital skills of the workforce to the model may also give a more complete picture of digital transformation in manufacturing companies.

## VIII. REFERENCES

- [1] Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2017). Maturity and readiness model for Industry 4.0 strategy. In *Industry 4.0: Managing the Digital Transformation* (pp. 61-94). Springer.
- [2] Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99-120.
- [3] Buer, S.-V., Strandhagen, J. O., & Chan, F. T. (2018). The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda. *International Journal of Production Research*, 56(8), 2924-2940.
- [4] Byrne, B. M. (2016). *Structural Equation Modeling With AMOS Basic Concepts, Applications, and Programming, Third Edition* (3rd Edition ed.). Routledge.
- [5] Castelo-Branco, I., Cruz-Jesus, F., & Oliveira, T. (2019). Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union. *Computers in Industry*, 107, 22-32.
- [6] DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48(2), 147-160.
- [7] Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39-50.
- [8] Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 Technologies: Implementation Patterns in Manufacturing Companies. *International Journal of Production Economics*, 210, 15-26.
- [9] Ghobakhloo, M. (2018). The Future of Manufacturing Industry: a Strategic Roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910-936.
- [10] Hair, J. F., Babin, B. J., Anderson, R. E., & Black, W. C. (2010). *Multivariate Data Analysis* (7th ed.). Pearson Education.
- [11] Hair, J. F., Babin, B. J., Anderson, R. E., & Black, W. C. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning.
- [12] Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2020). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2nd ed.). SAGE Publications.
- [13] Hermann, M., Pentek, T., & Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. 2016 49th Hawaii International Conference on System Sciences (HICSS).
- [14] Hoa, T. T. V., & Dong, D. T. (2019). Vietnamese Students' Awareness of The Fourth Industrial Revolution: An Empirical Research. *Journal of Economics and Development*, 2019(Special Issue), 134-162.
- [15] Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The Impact of Digital Technology and Industry 4.0 on the Ripple Effect and Supply Chain Risk Analytics. *International Journal of Production Research*, 57(3), 829-846.

- [16] Ivanov, D., Sokolov, B., & Dolgui, A. (2014). The Ripple effect in Supply Chains: Trade-off 'Efficiency-flexibility-resilience' in Disruption Management. *International Journal of Production Research*, 52(7), 2154-2172.
- [17] Kagermann, H. (2014). Change through Digitization—Value Creation in the Age of Industry 4.0. In *Management of Permanent Change* (pp. 23-45). Springer.
- [18] Kagermann, H., & Wahlster, W. (2022). Ten Years of Industrie 4.0. *Sci*, 4(3), 26.
- [19] Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, 6(4), 239-242.
- [20] Li, L., Su, F., Zhang, W., & Mao, J. Y. (2018). Digital Transformation by SME Entrepreneurs: A Capability Perspective. *Information Systems Journal*, 28(6), 1129-1157.
- [21] Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2018). A Critical Review of Smart Manufacturing & Industry 4.0 Maturity Models: Implications for Small and Medium-sized Enterprises (SMEs). *Journal of Manufacturing Systems*, 49, 194-214.
- [22] Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The Industrial Management of SMEs in the Era of Industry 4.0. *International Journal of Production Research*, 56(3), 1118-1136.
- [23] Ramdani, B., Kawalek, P., & Lorenzo, O. (2009). Predicting SMEs' Adoption of Enterprise Systems. *Journal of Enterprise Information Management*, 22(1-2), 10-24.
- [24] Rießmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. *Boston Consulting Group*, 9(1), 54-89.
- [25] Schumacher, A., Erol, S., & Sihm, W. (2016). A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*, 52, 161-166.
- [26] Schwab, K. (2016). *The Fourth Industrial Revolution*. World Economic Forum.
- [27] Sommer, L. (2015). Industrial Revolution-industry 4.0: Are German Manufacturing SMEs the First Victims of this Revolution? *Journal of Industrial Engineering and Management*, 8(5), 1512-1532.
- [28] Sony, M., & Naik, S. (2020). Critical Factors for the Successful Implementation of Industry 4.0: A Review and Future Research Direction. *Production Planning & Control*, 31(10), 799-815.
- [29] Teece, D. J. (2007). Explicating Dynamic Capabilities: The Nature and Microfoundations of (sustainable) Enterprise Performance. *Strategic Management Journal*, 28(13), 1319-1350.
- [30] Tornatzky, L. a. F., M. (1990). *The Processes of Technological Innovation*. Lexington Books.
- [31] Tortorella, G. L., & Fettermann, D. (2018). Implementation of Industry 4.0 and Lean Production in Brazilian Manufacturing Companies. *International Journal of Production Research*, 56(8), 2975-2987.
- [32] Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0—a Glimpse. *Procedia Manufacturing*, 20, 233-238.
- [33] Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, 27(3), 425-478.
- [34] Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly*, 36(1), 157-178.
- [35] Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the Art and Future Trends. *International Journal of Production Research*, 56(8), 2941-2962.