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Assessing Industry 4.0 Readiness of SME Validated Multidimensional Model

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Abstract. As digital transformation accelerates across industries, small and medium enterprises (SMEs) risk lagging behind larger firms in leveraging technologies. To systematically assess preparedness, this research develops and validates a multifaceted model tailored to measure industry 4.0 readiness among SMEs based on awareness, technology adoption ability, managerial support and customer focus. Grounded in innovation diffusion theory, 31 indicators across five dimensions are rigorously derived using mixed methods, including literature review, expert judgments and confirmatory factor analysis on survey data of 120 SMEs. The unified model provides an actionable assessment to benchmark the digitalization levels of SMEs in developing competitive improvement plans that are aligned with Industry 4.0.

Keywords: Assessing, Digital Transformation, Industry 4.0 Readiness, SMEs

1. Introduction

The notion of Industry 4.0 has gained global prominence in the past five years. The advent of Industry 4.0 is anticipated to exert a substantial and advantageous impact, especially in developing countries like Indonesia. Given the significant social and economic impacts of the global Coronavirus (COVID-19) pandemic, the integration of digitalization and shift towards Industry 4.0 is becoming more widespread and essential across all sectors, including small and medium-sized firms (SMEs). It is anticipated that this can enhance the sector's adaptability, efficiency, and long-term viability, foster the growth of a knowledge-driven economy and society, and thus enhance the overall standard of living (Turkyilmaz et al., 2021).

Around 90-95% of SMEs dominate Indonesia's economy, which can be seen during the economic crisis. Indonesia still has a substantial market share (Nugroho, 2015). Therefore, the impact of SMEs on the Industrial Revolution 4.0 is very significant. In increasing business capabilities, the obstacles for SMEs are very complex, such as lack of skilled workforce, marketing techniques, capital, business management, and managerial and production control (Sari & Santoso, 2019; Wijaya et al., 2017). Moreover, technology adoption is often not a priority for SMEs. Only around 58.6% of SMEs use information technology and computers in business activities (Nugroho, 2015). Some of the obstacles SMEs face in applying technology to Industry 4.0 include SMEs not having a competent workforce, difficulties in investing in new technology and reaching new areas in production and product development and production (Faller & Feldmüller, 2015).

The statistics about the limited implementation rates of Industry 4.0 technologies among small and medium-sized enterprises (SMEs) emphasize the pressing need for this research. For instance, research conducted in Indonesia revealed that a substantial majority of small and medium enterprises (SMEs) were in the first stages of adopting Industry 4.0. Out of the SMEs polled, 56% were classified as beginners, while 14% were considered outsiders, indicating no intention of implementing Industry 4.0 (Tama et al., 2021). A recent case study conducted in Malaysia emphasized the necessity for small and medium-sized enterprises (SMEs) to enhance their competitiveness by adopting Industry 4.0 principles. However, the study also identified the existing deficiencies and identified areas that require development for the complete adoption of Industry 4.0 (Azhar et al., 2021). These numbers indicate a significant deficiency in the preparedness and implementation of Industry 4.0 technologies among small and medium-sized enterprises (SMEs), emphasizing the necessity for a comprehensive framework that can effectively evaluate and assist SMEs in their shift towards Industry 4.0

In accelerating SMEs in Industry 4.0, it is necessary to prepare several factors that cannot be separated from the SME players themselves. Assessing a business's level of readiness for adopting innovations is one of the significant prerequisites for developing and keeping up with the flow of market developments. So, in this case, communication and information technology are factors that play an essential role in the world of industry and business (Aboelmaged, 2014). So, measuring readiness to enter Industry 4.0 in SMEs is very important to study now.

Industry 4.0 readiness measurement models often focus on large companies (Akdil et al., 2018; Lichtblau et al., 2015; Tan et al., 2019), and only a few focus on SMEs. However, there are still few who focus on SMEs in general. Previous research only focused on SMEs specifically, such as in the manufacturing sector (Brozzi et al., 2021; Kolla et al., 2019; Sriram & Vinodh, 2020) and the textile sector (Utomo & Setiastuti, 2019). Previous research (Wijaya & Budiman, 2019) has focused on assessing the interest of SME players in DI. Yogyakarta is adopting technology in its business activities but not yet in all dimensions of measuring Industry 4.0 readiness.

Despite the global prominence of Industry 4.0 and its potential benefits, especially for developing countries like Indonesia, there exists a significant gap in the literature regarding the readiness of small and medium-sized enterprises (SMEs) for adopting Industry 4.0 technologies. While SMEs play a crucial role in Indonesia's economy, their adoption rate of Industry 4.0 technologies remains low, with

obstacles such as a lack of skilled workforce, inadequate marketing techniques, insufficient capital, and challenges in business management, managerial and production control, and technology investment. Current Industry 4.0 readiness models predominantly cater to larger companies, with only a limited focus on SMEs and even less on SMEs across a variety of sectors beyond manufacturing and textiles. This study aims to address this gap by developing a multidimensional model to assess the readiness of SMEs for Industry 4.0 adoption, considering the unique challenges and limitations they face. This model seeks to provide a comprehensive framework that can evaluate and assist SMEs in their transition towards Industry 4.0, thereby supporting the growth of a knowledge-driven economy and society, enhancing the standard of living, and enabling SMEs to become more adaptable, efficient, and sustainable in the long term. Therefore, the research focuses on assessing the preparedness of small and medium-sized enterprises (SMEs) for adopting Industry 4.0 while also identifying areas of limited understanding or missing information. Small and medium-sized enterprises (SMEs) encounter distinct obstacles that necessitate a tailored readiness strategy, as opposed to larger organizations that possess greater resources and capabilities for incorporating sophisticated technologies. This approach must consider the unique attributes and limitations of SMEs. The rationale behind the development of an SME-focused preparedness model arises from the acknowledgement that current models primarily cater to larger firms, neglecting to consider the distinct requirements and circumstances of SMEs.

In this study, the research inquiries revolve around identifying the precise dimensions that encapsulate the readiness of small and medium-sized enterprises (SMEs) for Industry 4.0 adoption. Questions arise regarding which factors contribute most significantly to SMEs' preparedness and how these dimensions can be effectively verified. The aim is to assess the level of readiness of SMEs for Industry 4.0 adoption by developing and testing a multidimensional model tailored to their specific needs. These inquiries seek to address the practical challenges faced by SMEs in adapting to Industry 4.0 technologies and to provide relevant insights applicable across various SME settings. By exploring these questions, researchers aim to offer valuable guidance and support to SMEs as they navigate the complexities of technological integration and strive for competitiveness in today's rapidly evolving business landscape.

2. Literature Review

2.1. Industry 4.0

Industry 4.0, a component of the Fourth Industrial Revolution, represents a novel phase in the industrial sector. It encompasses a process paradigm that is self-controlling and self-optimizing, enabling organizations to provide enhanced service levels and digitize their production processes. In turn, facilitates innovation in their business models (Bulak et al., 2016; Carvalho et al., 2018; Moeuf et al., 2020; Stentoft et al., 2019). Industry 4.0 presents potential for small and medium-sized enterprises (SMEs) through improved supply chains that incorporate efficient consumer responsiveness and possess a significant level of adaptability. Many SMEs in developing and developed nations are still unaware of digitalization and its potential impact on competition (Turkyilmaz et al., 2021).

2.2. Readiness Model Measurement

Research that measures Industry 4.0 readiness in SMEs, especially in developing countries like Indonesia, is still very limited. The research roadmap will also examine the obstacles to SMEs in Readiness in the Industrial 4.0 era (Horváth & Szabó, 2019; Masood & Sonntag, 2020; Mittal et al., 2018; Orzes et al., 2018; Wijaya et al., 2017). The Industry 4.0 readiness measurement models that have been discussed in previous research are limited to models for large companies (Akdil et al., 2018; Kumari et al., 2015; Lichtblau et al., 2015; Tan et al., 2019) and are also specific to certain sectors (Brozzi et al., 2021; Kolla et al., 2019; Sriram & Vinodh, 2020; Utomo & Setiastuti, 2019). These models have not been developed into a general SME measurement system. There are several weaknesses of these models, namely: a) they cannot be implemented directly to measure the readiness

of SMEs in general. b) the research only explains several measurement indicators and does not include dimensions of measuring Industry 4.0 readiness.

2.3. Indicators and Dimensions

The literature on measuring Industry 4.0 readiness in SMEs highlights a variety of models and dimensions, each with its own set of indicators and limitations. A thorough review of these models reveals a consensus on the importance of multidimensional approaches to assess readiness accurately, yet also points out the need for more comprehensive and SME-specific frameworks.

A study categorizes indications of SMEs' readiness for Industry 4.0 into five dimensions: Organizational Resilience, Manufacturing System, Infrastructure System, Digital Technology, and Data Transformation. The study confirmed the dependability of these dimensions with a Cronbach's alpha value of 0.926 (Nilubon Chonsawat & Sopadang, 2020). This model emphasizes the importance of digital transformation and infrastructure, yet it may not fully capture the nuances of SME readiness, such as managerial and organizational capabilities or the role of customer-based and collaboration dimensions. The Smart SMEs 4.0 maturity model is a significant addition to the sector. It encompasses dimensions such as production and operations, people competency, technology-driven processes, digital support, and business and organizational approaches. This methodology was utilized in case studies conducted in Thailand. It demonstrates its utility in evaluating an organization's readiness and guiding companies towards efficient implementation of Industry 4.0 (N Chonsawat & Sopadang, 2021). While comprehensive, the model could benefit from a deeper exploration of how SMEs understand and adapt to Industry 4.0 beyond technological readiness, including awareness and customer-based considerations. An exploratory sequential mixed-method study identified ten aspects of preparation for Industry 4.0, emphasizing their crucial importance across various sectors and types of organizations, such as SMEs and major corporations (Sony et al., 2021). This approach underscores the variability in readiness across different types of organizations but may not fully address the specific challenges and opportunities faced by SMEs in adopting Industry 4.0 technologies. Internal elements that contribute to SMEs' readiness for Industry 4.0 in emerging markets include operational, managerial, and technological preparedness. These aspects provide valuable information on the main drivers for adoption, such as financial capacity and anticipated advantages (Kee et al., 2023). This study points to the importance of understanding the specific context of SMEs in emerging markets, suggesting that readiness models need to consider the unique economic and operational environments of these enterprises.

In summary, while existing models provide valuable frameworks for assessing Industry 4.0 readiness, there is a clear need for models that incorporate new indicators or dimensions specifically tailored to SMEs. These should include a deeper understanding of Industry 4.0 (awareness), organizational and managerial capabilities, technology adoption, customer-based considerations, and collaboration. Such dimensions are crucial for capturing the full spectrum of SME readiness, addressing both the technological and non-technological aspects of Industry 4.0 adoption, and ensuring that readiness models are both comprehensive and applicable to the unique needs of SMEs.

3. Research Method

The aim of this study, as stated in this paper, is to provide a novel perspective on the dimensions and indicators utilized to evaluate the preparedness of small and medium-sized firms (SMEs) for Industry 4.0. The approach employed in this study comprises three primary stages: (1) Conducting research using available resources to develop a preliminary measurement for assessing the preparedness of an industry to adopt Industry 4.0. It includes identifying the dimensions, indicators, and instruments to be used. (2) Conduct a Focus Group Discussion (FGD) to get input from academics and practitioners regarding the suggested instruments and indicators, namely the Content Validity Ratio and Content Validity Index. (3) Validate the indicators by Confirmatory Factor Analysis, with input from practitioners.

3.1. Model Conceptual

The dimensions used in measuring Industry 4.0 readiness in SMEs are Understanding Industry 4.0 (Awareness), Organizational and Managerial, Technology, Customer-Based, and Collaboration. The relationship between dimensions and indicators for measuring Industry 4.0 readiness in SMEs is presented in Table 1.

Table 1: Dimensions and Indicators for Measuring Industry 4.0 Readiness In SMEs

No.	Dimension	Indicator	Instrument	References
1	Industry 4.0 Awareness (PI)	1. Knowledge regarding Industry 4.0	1. Business Owners know the Industry 4.0 concept (P11.1) 2. Industry 4.0 is an essential concept in managing business (P11.2) 3. Business owners know the benefits of interaction with the Industry 4.0 concept (P11.3)	(Brozzi et al., 2021; Tan et al., 2019)
		2. Potential results of implementing Industry 4.0	1. Business owners know the impact of Industry 4.0 development on business continuity (P12.1) 2. The potential results of implementing Industry 4.0 are pretty significant (P12.2) 3. It will be easier for SMEs to carry out their business activities if they adopt the Industry 4.0 concept (P12.3)	
2	Organization and Managerial (OM)	1. Management and leadership support,	1. Business Owners have an explicit vision regarding the development of SMEs related to Industry 4.0 (P21.1) 2. I believe the business owner/management has a suitable vision for SMEs (P21.2) 3. Business owners have a high commitment to resolving problems that may arise within the organization that have an impact on SMEs (P21.3)	(Moraliyska & Antonova, 2018; Nair et al., 2019; Stentoft et al., 2019)
		2. Industry 4.0 Implementation Strategy	1. Business owners know the opportunities and threats in developing their businesses. (P22.1) 2. Business owners have strategic plans for business development according to resources. (P22.2) 3. Business owners have a good understanding of appropriate business models. (P22.3)	
		3. The technical skills that exist within the organization	1. Business employees have good technical skills/skills in completing work (P23.1) 2. Business employees can think critically and innovatively in carrying out work (P23.2) 3. Business employees have good time management in carrying out work (P23.3)	
		4. Teamwork	1. Business owners can coordinate teams in carrying out work (P24.1) 2. Business employees have good communication skills between fellow employees and superiors. (P24.2) 3. Business employees can understand and have responsibility for their respective jobs. (P24.3)	
3	Technology (TC)	1. Convenience of using technology	1. SMEs have sufficient experience in operating technology in their business (P31.1) 2. Technology in SMEs is used to find sources of information and information that is needed. (P31.2) 3. Technology as a medium, as a tool that facilitates the delivery of information so that it can be received and understood easily in SMEs. (P31.3) 4. Technology is used as a developer of learning skills, developing information technology-based skills with applications in business (P31.4)	(Castelo-Branco et al., 2019; Sommer, 2015; Teh & Kee, 2019; Trstenjak et al., 2019; Truvé et al., 2019; Wijaya & Budiman, 2019)
		2. Overcoming technological insecurities	1. SMEs have a sound data security system in their business (P32.1) 2. SMEs have a strategy for following up if there is theft of information or data from their business (P32.2) 3. SMEs are responsive in overcoming information and data	

No.	Dimension	Indicator	Instrument	References
			security problems (P32.3)	
		3. Compatibility with existing technology	1. SMEs already use technology in aspects of their production activities (P33.1) 2. SMEs already use technology in their marketing aspects (P33.2) 3. SMEs already use technology to interact with stakeholders (P33.3) 4. SMEs already use technology in their business processes (warehouse, administration and others) (P33.4)	
		4. Internet Infrastructure	1. SMEs have high bandwidth connectivity with the internet (P34.1) 2. SMEs have policies regarding internet operations in their business activities (P34.2) 3. SMEs have sufficient internet infrastructure to run their business (P34.3) 4. Current business systems can adapt to the implementation of Industry 4.0 (P34.4)	
4	*Customer Based (CB)*	1. Customer-focused innovation,	1. SMEs make products based on consumer needs (P41.1) 2. SMEs have marketing innovations in reaching their consumers (P41.2) 3. SMEs have advantages and uniqueness in their business activities (products, business processes) in achieving their consumers (P41.3)	(Moraliyska & Antonova, 2018; Truvé et al., 2019; Zaidi & Belal, 2019)
		2. Customer expectations	1. SMEs have fast customer service (P42.1) 2. SMEs have digital channels that offer what customers expect (P42.2) 3. SMEs are active in asking for feedback from customers (P42.3) 4. SMEs have services related to personalization and product and service offerings (P42.4)	
5	Collaboration (CL)	1. Competition and pressure from business partners	1. Business people are encouraged to improve the quality of products or services offered due to pressure from competitors (P51.1) 2. Business people are responsive in responding to complaints or criticism from customers (P51.2) 3. Business actors constantly try to increase brand awareness of their business (P51.3) 4. Business people can analyse target market research and the business competitive environment (P51.4)	(Bär et al., 2018; Faller & Feldmüller, 2015; Hamidi et al., 2018; Mittal et al., 2018; Trstenjak et al., 2019)
		2. Supply chain management and collaboration	1. Business actors have business partners in managing their business (P52.1) 2. Business actors can collaborate with work partners (Stakeholders: suppliers, government or other parties) (P52.2) 3. Business people have high intensity in collaborating with their business partners (P52.3)	
		3. Sustainability	1. SMEs always routinely carry out evaluations related to their business processes (P53.1) 2. SMEs can make improvements related to evaluation so that they can increase business value in the long term (P53.2) 3. SMEs can implement social, economic and environmental values in their business strategies. (P53.3)	
		4. Global Engagement	1. Business actors can expand their business overseas (P54.1) 2. Business actors have global partners to support their business processes (P54.2) 3. Business actors can access international involvement in their business processes (HR, Technology, materials)	

No.	Dimension	Indicator	Instrument	References
			(P54.3)	

3.2. Data Collections and Processing

The research object is SMEs in Indonesia with stakeholders, namely academics, government and business actors. The techniques used are a deductive approach through literature study and an inductive approach in developing research indicators and instruments. The sampling technique employed for this study is purposive sampling, which was chosen for its effectiveness in selecting respondents who are most likely to offer relevant and insightful data aligned with the study's objectives. In purposive sampling, participants are deliberately chosen based on specific characteristics or criteria determined by the researcher's judgment. This method is particularly useful for qualitative research that focuses on a particular subgroup within the population, allowing researchers to target individuals who possess the desired attributes or experiences relevant to the research questions.

Data processing during brainstorming uses Content Validity Ratio and Content Validity Index techniques, which are then tested again using Confirmatory Factor Analysis using SmartPLS 4 software. The study outlined aims to offer a fresh perspective on assessing the readiness of small and medium-sized enterprises (SMEs) for Industry 4.0 by proposing novel dimensions and indicators. The methodology encompasses three distinct phases, each designed to progressively refine and validate the measurement instruments and indicators for evaluating SMEs' preparedness for Industry 4.0.

1. Preliminary Measurement Development

The initial phase involves comprehensive research utilizing existing literature to construct a preliminary framework for assessing Industry 4.0 readiness. This step is critical for identifying relevant dimensions, indicators, and instruments that will form the basis of the measurement model. The research employs a deductive approach, drawing from scholarly articles, industry reports, and existing models to pinpoint the essential elements that should be included in the readiness assessment.

2. Focus Group Discussion (FGD)

The second phase of the study involves conducting Focus Group Discussions (FGDs) to gather insights from a diverse group of stakeholders, including academics, practitioners, and government representatives. The objective of these discussions is to solicit feedback on the proposed measurement instruments and indicators, specifically focusing on their relevance and comprehensiveness. This stage employs qualitative methods to ensure the content validity of the model, utilizing tools such as the Content Validity Ratio (CVR) and Content Validity Index (CVI) to assess the appropriateness of the selected indicators quantitatively. Data collection was comprised of 20 respondents in the first and second stages: business academics, business actors, and government. These respondents will determine the construct of developing a measurement model for Industry 4.0 readiness in SMEs. This number of respondents is considered sufficient for research purposes, as the main focus is on developing the measurement model. In the CVR method, the quality and importance of each construct are assessed based on the level of consensus among respondents regarding the proposed items. By selecting respondents who possess relevant understanding and experience in the context of Industry 4.0 and SMEs, researchers can ensure that the obtained data can provide valuable insights in constructing a valid and reliable measurement model. By limiting the number of respondents and focusing on gathering high-quality data, this research can maximize resource efficiency and ensure that the results are dependable in developing an accurate measurement model for Industry 4.0 readiness in SMEs.

3. Indicator Validation

The final phase involves the empirical validation of the indicators through Confirmatory Factor Analysis (CFA), incorporating feedback from practitioners. Confirmatory Factor Analysis (CFA) is a statistical method used to assess the validity and reliability of measurement instruments by confirming or rejecting hypothesized relationships between observed variables and latent constructs. It evaluates the

fit between observed data and a theoretical model, providing insights into how well the observed variables represent the underlying constructs (Brown, 2015). This stage is crucial for confirming the structural validity of the measurement model and ensuring that the indicators accurately capture the dimensions of Industry 4.0 readiness among SMEs. Data collection for the CFA test using 120 respondents from micro, small, and medium enterprises in many sectors. This sample size is deemed sufficient for the analysis, as it allows for a comprehensive examination of the underlying constructs related to Industry 4.0 readiness. Also, including respondents from diverse sectors ensures the representation of different perspectives and experiences, enhancing the validity and generalizability of the findings. A focused sample size enables researchers to maintain quality control over the data collection process, ensuring that the collected responses are reliable and consistent.

Initially, performance indicators suggested in existing literature are disseminated to academics and professionals in SMEs and Digital Transformation. It is done through an open questionnaire, as shown in Table 1. Respondents can offer recommendations or suggestions regarding additional indicators and instruments that should be included. It is anticipated to enhance the precision, feasibility, and comprehensiveness of the indicators. The participants included three scholars and 17 professionals from small and medium-sized businesses. Respondent details are in Table 2 below.

Table 2: Respondent Data

No	Role	Expertise	Experience (years)
1	Practitioner	Culinary	4
2	Practitioner	Craft	4
3	Practitioner	Industry	2
4	Practitioner	Technology	15
5	Practitioner	Fashion	10
6	Academic	Marketing	5
7	Practitioner	Culinary	4
8	Practitioner	Craft	4
9	Practitioner	Craft	6
10	Practitioner	Craft	14
11	Practitioner	Culinary	11
12	Practitioner	Culinary	11
13	Academic	Operation Management	8
14	Academic	Entrepreneurship	5
15	Practitioner	Fashion	8
16	Practitioner	Culinary	3
17	Practitioner	Craft	25
18	Practitioner	Craft	8
19	Practitioner	Automatic	5
20	Practitioner	Services	3

The results of the FGD, which was carried out in stage 1, processed the questionnaire results based on data from respondents through the Content Validity Ratio test with the formulation below (Lawshe, 1975):

$$\text{CVR} = \frac{n_e - (\frac{N}{2})}{\frac{N}{2}}$$

where

CVR: content validity ratio

N: the quantity of specialists

n_e: The count of specialists who assigned a rating of 3 or relevant.

Table 3: Minimum CVR Values For Different Numbers of Panelists (or Experts)

Number of Panelist	Minimum Acceptable CVR Ratio
5	0.99
6	0.99
7	0.99
8	0.75
9	0.78
10	0.62
11	0.59
12	0.56
13	0.54
14	0.51
15	0.49
20	0.42
25	0.37
30	0.33
35	0.31
40	0.29

The respondents in this second stage were the same, consisting of 3 academics and 17 practitioners. Validate the instrument using CVI (Content Validity Index), where respondents were given the results of FGD stage 1 with a different measurement scale, namely with binary scoring where one was declared valid and 0 was declared invalid. This stage 2 FGD results show that all items are declared valid, where the limit values are as shown in Table 4 below.

Table 4: Number of Experts and Criteria for Determining Content Validity With CVI

Expert Number	CVI Value	References
3-5	1	Polit and Beck (2006); Polite et al. (2007)
6-8	0,83	Lynn (1986)
≥ 9	0,78	Lynn (1986)

4. Results and Analysis

4.1. Focused Group Discussion (First Stage)

Through the calculation of the Content Validity Ratio (CVR) with 20 experts or panellists, the obtained validity score is 0.42. If the calculated value falls below 0.42, it is considered invalid. This threshold serves as a benchmark to determine the adequacy of the items assessed by the experts in relation to the construct being measured. Items with CVR scores below 0.42 are deemed to lack sufficient content validity, indicating that they do not adequately represent the intended construct. Consequently, such items may need to be revised or eliminated to ensure the reliability and validity of the measurement instrument. Based on the calculation findings, out of the 53 question items used to assess the readiness of SMEs in adopting Industry 4.0, only 45 were deemed valid, while eight items were deemed invalid, as shown in Table 5.

Table 5: Results of CVR

No	Dimension	Instrument	CVR	Note
1	Industry 4.0 Awareness	P11.1	0,5	Valid
2		P11.2	0,9	Valid
3		P11.3	0,7	Valid

No	Dimension	Instrument	CVR	Note
4		P12.1	0,8	Valid
5		P12.2	0,8	Valid
6		P12.3	0,5	Valid
7	Organization and Managerial	P21.1	0,5	Valid
8		P21.2	0,7	Valid
9		P21.3	0,6	Valid
10		P22.1	0,8	Valid
11		P22.2	0,7	Valid
12		P22.3	0,2	Invalid
13		P23.1	0,5	Valid
14		P23.2	0,5	Valid
15		P23.3	0,5	Valid
16		P24.1	0,6	Valid
17		P24.2	0,7	Valid
18		P24.3	0,7	Valid
19	Technology	P31.1	0,2	Invalid
20		P31.2	0,6	Valid
21		P31.3	0,7	Valid
22		P31.4	0,6	Valid
23		P32.1	0,5	Valid
24		P32.2	0	Invalid
25		P32.3	0,5	Valid
26		P33.1	0,5	Valid
27		P33.2	0,6	Valid
28		P33.3	0	Invalid
29		P33.4	-0,4	Invalid
30		P34.1	0,5	Valid
31		P34.2	0,5	Valid
32		P34.3	0,6	Valid
33		P34.4	-0,1	Invalid
34	Customer Based	P41.1	0,6	Valid
35		P41.2	0,7	Valid
36		P41.3	0,8	Valid
37		P42.1	0,5	Valid
38		P42.2	0,5	Valid
39		P42.3	0	Invalid
40		P42.4	0,5	Valid
41	Collaboration	P51.1	0,5	Valid
42		P51.2	0,6	Valid
43		P51.3	0,6	Valid
44		P51.4	0,5	Valid
45		P52.1	0,5	Valid
46		P52.2	0,7	Valid
47		P52.3	0,5	Valid
48		P53.1	0,5	Valid
49		P53.2	0,5	Valid
50		P53.3	0,7	Valid
51		P54.1	-0,1	Invalid
52		P54.2	0,5	Valid
53		P54.3	0,5	Valid

4.2. Focused Group Discussion (Second Stage)

Through the calculation of the Content Validity Index (CVI) with more than nine experts, the established validity score is 0.78. Should the computed value fall below 0.78, it is deemed invalid. This threshold serves as a critical benchmark in evaluating the adequacy of the items assessed by the experts concerning the construct under consideration. Items that yield CVI scores below 0.78 are considered to

lack sufficient content validity, indicating potential inadequacies in representing the intended construct. Consequently, such items may necessitate revision or removal to ensure the reliability and validity of the measurement instrument. This meticulous evaluation process ensures that the instrument effectively captures the essence of the construct being measured, thereby enhancing its credibility and utility in assessing the readiness of small and medium enterprises for Industry 4.0 adoption. This second FGD process was used to revalidate the results of the 45 questionnaires that had been declared valid. This stage 2 FGD results show that all items are declared valid, where the limit values are as shown in Table 6 below.

Table 6: Content Validity Index Results

No	Dimension	Instrument	CVI	Note
1	Industry 4.0 Awareness	P11.1	0,95	Valid
2		P11.2	1	Valid
3		P11.3	1	Valid
4		P12.1	1	Valid
5		P12.2	1	Valid
6		P12.3	1	Valid
7	Organization and Managerial	P21.1	0,95	Valid
8		P21.2	1	Valid
9		P21.3	1	Valid
10		P22.1	0,95	Valid
11		P22.2	0,95	Valid
12		P23.1	0,95	Valid
13		P23.2	1	Valid
14		P23.3	0,95	Valid
15		P24.1	1	Valid
16		P24.2	1	Valid
17		P24.3	1	Valid
18	Technology	P31.2	1	Valid
19		P31.3	0,95	Valid
20		P31.4	0,95	Valid
21		P32.1	0,85	Valid
22		P32.3	0,75	Valid
23		P33.1	0,8	Valid
24		P33.2	1	Valid
25		P34.1	0,9	Valid
26		P34.2	0,95	Valid
27		P34.3	1	Valid
28	Customer Based	P41.1	0,95	Valid
29		P41.2	1	Valid
30		P41.3	1	Valid
31		P42.1	1	Valid
32		P42.2	0,95	Valid
33		P42.4	0,9	Valid
34	Collaboration	P51.1	1	Valid
35		P51.2	1	Valid
36		P51.3	1	Valid
37		P51.4	1	Valid
38		P52.1	0,95	Valid
39		P52.2	1	Valid
40		P52.3	0,95	Valid
41		P53.1	0,95	Valid
42		P53.2	1	Valid
43		P53.3	1	Valid
44		P54.2	0,9	Valid
45		P54.3	0,9	Valid

4.3. Confirmatory Factor Analysis (CFA)

Data was collected at this stage by a questionnaire survey that was delivered to micro, small, and medium firms. The survey had a total of 120 responses, with the following distribution across different sectors: culinary (33.7%), services (11%), craft (24%), fashion (27.3%), and 4% in other sectors. Confirmatory factor analysis, as described by Hair et al. (2014), is a component of Structural Equation Modelling (SEM) that facilitates the evaluation of how variables effectively quantify the number of components. In the context of CFA, factors might be referred to as constructs. Factor analysis is a statistical method used to analyse the relationship between different variables and uncover the underlying structure of a study. A high partial correlation in component analysis is considered to have both practical and statistical relevance when it exceeds a threshold of 7, which is commonly used as a rule of thumb based on conceptual reasoning. Nevertheless, Bartlett's test of sphericity with a significance level greater than 0.05 suggests a satisfactory correlation among the concept variables, allowing for the continuation of factor analysis (Hair Jr et al., 2010). The CFA results on the construct variable measuring industry 4.0 readiness in SMEs against the indicators can be seen in the following Figure 1.

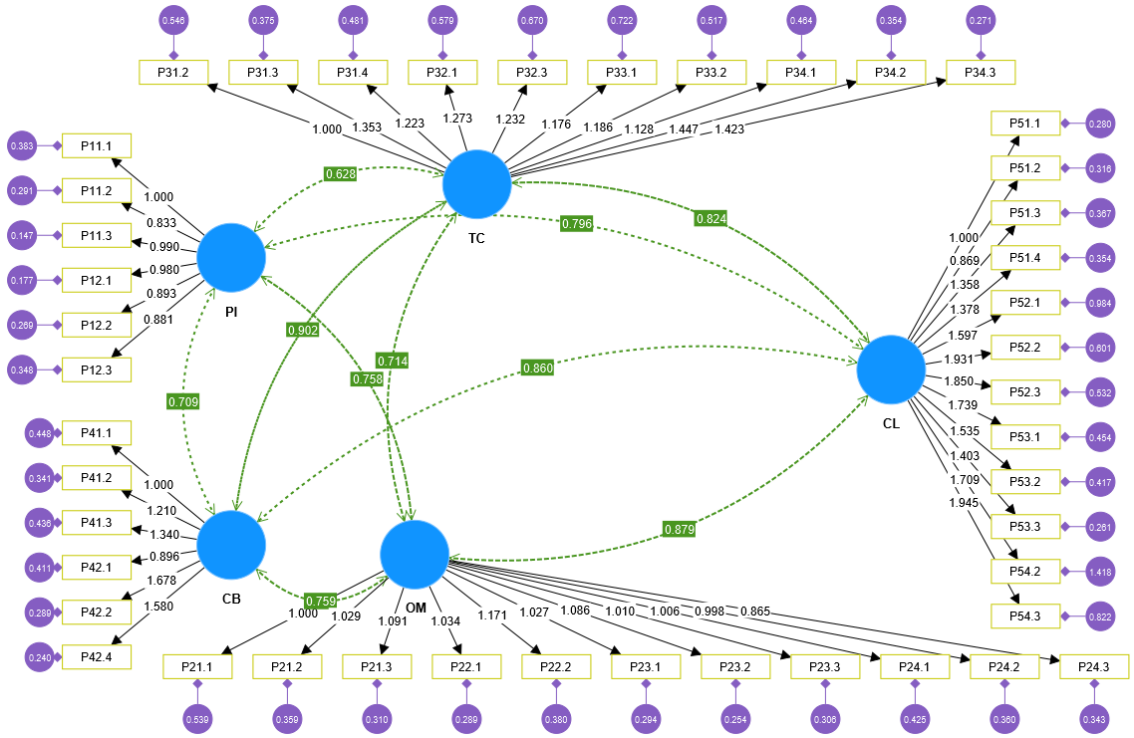

Fig. 1: CFA Empirical Model for Measuring Industry 4.0 Readiness in SMEs (Stage 1)
Source: Primary Data processed 2023

4.3.1. Outer Loadings Analysis 1

Analysis of Outer Loadings 1

Factor loadings indicate the correlation between indicators and their constructs. Indicators with low loading values indicate that they do not effectively contribute to the measurement model. The expected loading value is > 0.7 as shown in Table 7 below.

Tabel 7. Outer Loadings Tahap 1

	CB	CL	OM	PI	TC
P11.1				0.830	
P11.2				0.819	
P11.3				0.922	

	CB	CL	OM	PI	TC
P12.1				0.907	
P12.2				0.846	
P12.3				0.809	
P21.1			0.673		
P21.2			0.754		
P21.3			0.795		
P22.1			0.790		
P22.2			0.786		
P23.1			0.784		
P23.2			0.822		
P23.3			0.774		
P24.1			0.718		
P24.2			0.743		
P24.3			0.703		
P31.2					0.656
P31.3					0.818
P31.4					0.750
P32.1					0.732
P32.3					0.695
P33.1					0.665
P33.2					0.728
P34.1					0.729
P34.2					0.842
P34.3					0.869
P41.1	0.644				
P41.2	0.760				
P41.3	0.753				
P42.1	0.619				
P42.2	0.869				
P42.4	0.876				
P51.1		0.662			
P51.2		0.586			
P51.3		0.724			
P51.4		0.735			
P52.1		0.601			
P52.2		0.759			
P52.3		0.764			
P53.1		0.770			
P53.2		0.743			
P53.3		0.789			
P54.2		0.557			
P54.3		0.708			

The factor loading value indicates the degree of association between the indicator and the construct. A low loading value of an indicator reflects the ineffectiveness of the measuring model. It is known that there are instrument variables that have outer loading values of more than >0.7, namely P21.1, P31.2, P32.2, P33.1, P41.1, P42.1, P51.1, P51.2, P52.1, P54.2 so that the data must be removed and the CFA testing process carried out again (stage 2). In the second stage, a CFA test was carried out, and the results showed that there were still three variable instruments that were not yet valid, namely P31.4,

P51.3, and P54.3. In the third stage, a CFA test was carried out where all instrument variables were declared valid because they were >0.7, as in Figure 2 below.

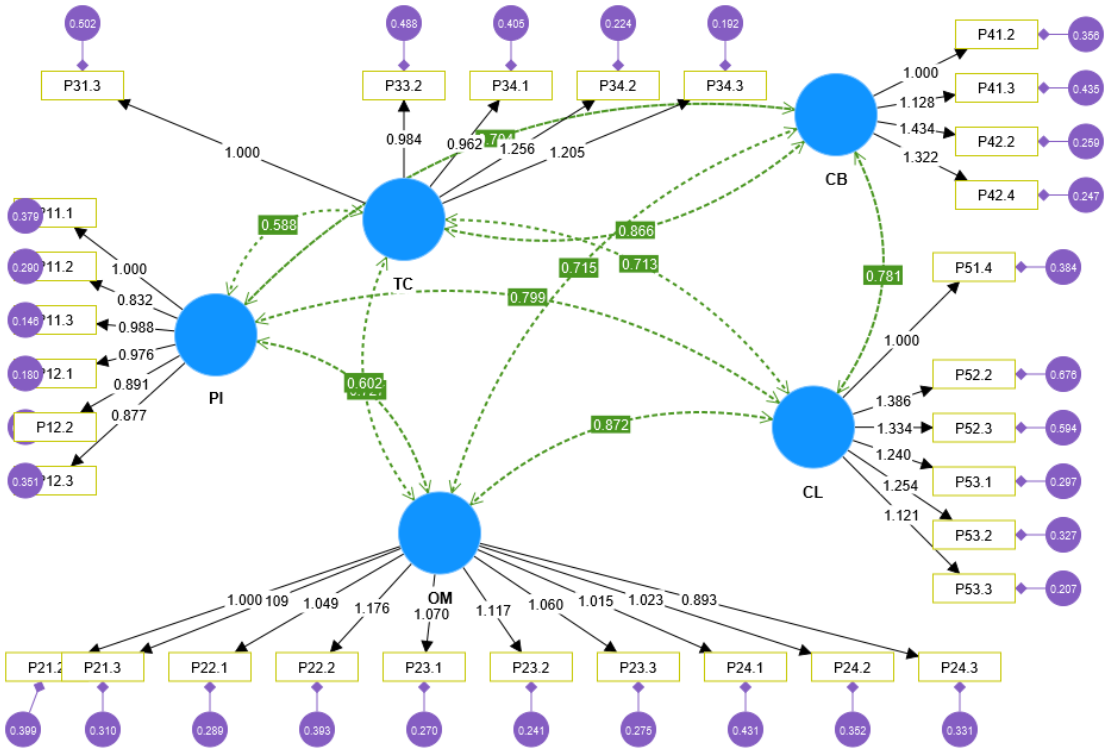

Fig. 2: CFA Empirical Model for Measuring Industry 4.0 Readiness in SMEs (Final)
Source: Primary Data processed 2023

4.3.2. Outer Loadings Analysis 2

The factor loading value indicates the degree of association between the indicator and the construct. A low loading value for an indication suggests that the indicator is ineffective in the measurement model. The anticipated loading value is more than 0.7, as shown in Table 8 below.

Table 8: Outer Loadings (Final)

	CB	CL	OM	PI	TC
P11.1				0.833	
P11.2				0.819	
P11.3				0.923	
P12.1				0.905	
P12.2				0.847	
P12.3				0.808	
P21.2			0.722		
P21.3			0.795		
P22.1			0.789		
P22.2			0.777		
P23.1			0.805		
P23.2			0.832		
P23.3			0.800		
P24.1			0.713		
P24.2			0.750		
P24.3			0.715		
P31.3					0.746
P33.2					0.746
P34.1					0.768
P34.2					0.903
P34.3					0.909

	CB	CL	OM	PI	TC
P41.2	0.747				
P41.3	0.753				
P42.2	0.884				
P42.4	0.872				
P51.4		0.708			
P52.2		0.723			
P52.3		0.732			
P53.1		0.816			
P53.2		0.806			
P53.3		0.837			

4.3.3. AVE and Discriminant Validity Analysis

To assess the convergence of the validity of reflective constructs, it is imperative to consider both the external loadings of indicators as well as the average variance extracted (AVE). AVE values that are equal to or surpass 0.50 signify that, in general, the construct elucidates more than half of the variance of the indicator. Conversely, an AVE value below 0.50 suggests that the variability attributable to errors in the items surpasses the variability elucidated by the construct. The AVE value in Table 9 exceeds 0.5. Discriminant validity pertains to the extent to which an idea is truly separate from others based on empirical criteria. Demonstrating discriminant validity entails showing that a construct is unique and contains phenomena that are not explained by other constructs in the model. The assessment of discriminant validity can be conducted through the utilization of the Fornell-Larker criterion and cross-loading tests. The Fornell-Larker Criterion examination is accomplished through the juxtaposition of the Average Variance Extracted (AVE) value against those of other latent variables. The criterion being satisfied must entail that the correlation coefficient of a given AVE with its corresponding variable construct surpasses those coefficients associated with alternate variable constructs. It can be seen in each variable column's diagonal and vertical direction. Table 10 states that each instrument is declared valid because the value is >0.9.

Table 9: Average Variance Extracted (AVE)

	Cronbachs alpha (standard.)	Cronbachs alpha (unstandard.)	Composite reliability (rho_c)	Average variance extracted
CB	0.887	0.887	0.892	0.667
CL	0.897	0.891	0.893	0.596
OM	0.936	0.935	0.936	0.594
PI	0.944	0.943	0.943	0.734
TC	0.907	0.907	0.911	0.669

Table 10: Discriminant Validity

	CB	CL	OM	PI	TC
CB					
CL	0.803				
OM	0.733	0.881			
PI	0.716	0.798	0.723		
TC	0.883	0.741	0.634	0.588	

4.4. Synthesis of Industry 4.0 Readiness Measurements in SMEs

Indicators for measuring Industry 4.0 in SMEs and SMEs are important to develop. It is used to help assess SMEs' maturity and readiness level for digital transformation and adoption of Industry 4.0 practices. Based on validity measurements through 3 stages (CVR, CVI and CFA), five dimensions, 14 indicators and 31 instruments are considered valid for measuring industry 4.0 readiness in SMEs in Indonesia, as shown in Figure 3.

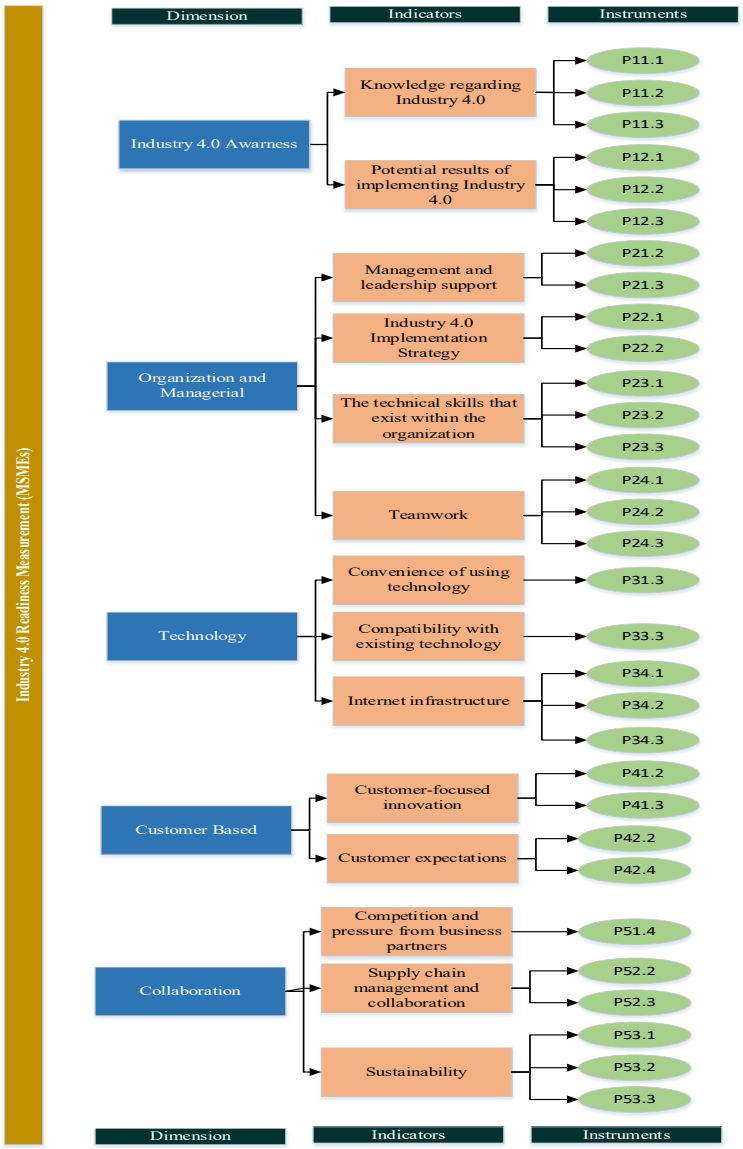

Fig. 3: Synthesis of Industry 4.0 Readiness Measurements in SMEs

The refinement of the model for assessing Industry 4.0 readiness in SMEs, as described, focuses on streamlining and emphasizing the indicators most critical to the successful adoption and implementation of Industry 4.0. This approach is likely informed by empirical research and theoretical discussions that highlight the importance of these specific areas for SMEs navigating the transition to Industry 4.0.

Industry 4.0 Awareness retaining knowledge regarding Industry 4.0 and the potential results of implementing Industry 4.0 underscores the necessity for SMEs to understand both the conceptual framework of Industry 4.0 and the tangible benefits it can offer. This dual focus ensures that SMEs are not only aware of Industry 4.0 but are also motivated by the potential for improved efficiency, innovation, and competitive advantage. Literature often points to awareness and understanding as foundational steps for successful digital transformation (Schumacher et al., 2016). Organization and Managerial also focuses on the inclusion of management and leadership support, Industry 4.0 implementation strategy, the technical skills that exist within the organization, and teamwork, highlighting the critical role of human and strategic elements in the transition to Industry 4.0. Leadership is frequently cited as a key driver for change, providing the vision and support necessary for navigating the complexities of digital transformation (Hess et al., 2020). Technology indicators only focus on the

convenience of using technology to overcome technological insecurities, and internet Infrastructure reflects an understanding of the practical and psychological barriers to technology adoption in SMEs. Addressing these barriers is crucial for ensuring that SMEs can effectively integrate new technologies into their operations. The emphasis on infrastructure also acknowledges the foundational role of reliable internet access in enabling Industry 4.0 technologies (Kagermann et al., 2013). Customer-based highlighting of customer-focused innovation and customer expectations recognizes the shifting market dynamics and the need for SMEs to be more responsive and adaptive to customer needs. It aligns with discussions on the importance of customer-centric approaches in leveraging Industry 4.0 for business model innovation (Porter & Heppelmann, 2014). Collaboration maintains indicators related to competition and pressure from business partners, supply chain management and collaboration, and sustainability. It may reflect a strategic focus on strengthening local networks and resilience in the face of Industry 4.0 challenges (Rüßmann et al., 2015).

5. Discussion

The dimension of understanding Industry 4.0, where the indicators are knowledge and the potential results of implementing Industry 4.0, is the most important in measuring Industry 4.0 readiness in SMEs, especially in developing countries. Understanding Industry 4.0 is key because it's the foundation for all further knowledge and action plans. Without a full understanding of Industry 4.0, including its tech, methods, and principles, organizations can't effectively tackle digital transformation. It goes beyond just the tech details to include the impact on business operations and employees. It's like knowing the game rules before playing; without this, making smart decisions or plans is almost impossible. Also, focusing on the expected benefits of Industry 4.0 as key goals highlights the need for planning and acting with the results in mind. Knowing about Industry 4.0 is one thing, but understanding what it can do for a company is another. This approach helps companies aim for long-term gains like better efficiency, adaptability, and market edge. Knowing these potential benefits helps set clear targets and motivates action; plus, it is useful for explaining the benefits to others and getting their support. It will be easier for SMEs to carry out business activities if they adopt the Industry 4.0 concept. It is in line with research from (Safar et al., 2020) that attaining a high degree of awareness and fundamental understanding of the concept of Industry 4.0 is crucial to transition to an intelligent environment effectively. Therefore, awareness of Industry 4.0 must continue to be promoted, especially among SMEs in developing countries.

Apart from management support, leadership, implementation of Industry 4.0 strategies, and organizational and managerial issues are also important in supporting Industry 4.0. Leaders who know business conditions and challenges related to their business will certainly mobilize visionaries in their business development units through planning business development strategies according to the right resources. An individual at the helm of a constructive transformation group or organization must establish a clear path and ensure that individuals are in sync with the necessary techniques to accomplish the envisioned goals. It is in line with (Guzmán et al., 2020). Effective leadership is crucial in organizations to effectively foster a culture of innovation. Leaders have an essential role in driving the transition to Industry 4.0. The leadership approach for I4.0 should be characterized by openness, fostering a culture of continuous learning and innovation, and prioritizing the expansion of knowledge and unconventional thinking (Sivathanu & Pillai, 2018). Also, when management fully backs Industry 4.0, it shows the company is ready to change, which is key for innovation. Leaders in small and medium enterprises (SMEs) are crucial for overcoming digital transformation challenges, like choosing the right tech and matching it with business aims. Their passion for Industry 4.0 can motivate everyone to work towards common goals. Also, applying Industry 4.0 strategies needs a broad approach, not just using new tech but also fixing company and management issues. It means updating business processes, gaining new skills, and making sure employees are ready for what's coming. Good leadership makes sure these plans are put into action and become a core part of the business, helping it become more

flexible, efficient, and competitive. Facing issues like change resistance, skill shortages, and making sure IT and business goals match are typical Industry 4.0 challenges. Strong leadership and support from management can help tackle these problems by promoting a culture of ongoing learning, flexibility, and readiness to change, which are all vital for successfully using Industry 4.0.

Technology is one of the urgent things in business management. Technology can increase the effectiveness and efficiency of a business. The Technology indicators, focusing on the convenience of using technology, compatibility with existing technology, and internet infrastructure while excluding overcoming technological insecurities, might be attributed to the emphasis on practical and infrastructural readiness over psychological barriers. This prioritization suggests that addressing tangible technology challenges and ensuring seamless integration and user-friendliness of new technologies are seen as more immediately impactful for SMEs' Industry 4.0 readiness. The rationale could be that once the technological infrastructure is robust and user-friendly, it naturally mitigates insecurities related to technology adoption. The use of technology can provide excellent opportunities for SME business development. Technology has also opened a more comprehensive market reach through various online platforms. It aligns with (Bai et al., 2020), where Industry 4.0 technology can provide innovation and extraordinary competitive growth. It can also improve the business system. However, overcoming technological security, especially for SMEs in developing countries, is still very difficult. This is due to the high initial investment costs. Many of the latest technologies require significant investments in infrastructure and employee training, which may be difficult for SMEs with limited resources to afford.

Measuring the readiness for Industry 4.0 involves a comprehensive evaluation that extends beyond mere technological adoption. It is intricately linked to how innovation is cultivated, particularly in alignment with what customers need and anticipate. Small and Medium-sized Enterprises (SMEs) are at the forefront of this shift, necessitating a keen focus on innovation that touches on several critical aspects. These include the development of new and improved products, the implementation of creative promotional strategies, and the optimization of distribution channels to ensure that their offerings reach the market effectively. (Müller & Däschle, 2018) Underscore the pivotal role of SMEs in this landscape. They highlight how these businesses, by adopting solutions powered by Industry 4.0 technologies, are not just responding to customer demands but are also setting the stage for further advancements. By doing so, SMEs are not only enhancing their operational processes but are also contributing to a cycle of continuous innovation and improvement, ensuring that they remain competitive and relevant in a rapidly evolving market. This approach underscores the symbiotic relationship between technological advancement and customer-centric innovation, positioning SMEs as key players in the transition towards Industry 4.0.

Collaboration plays a pivotal role in assessing Industry 4.0 readiness, with a focus on analyzing target market research and understanding the competitive business environment as key to developing business units. Supply chain management, effective collaboration, and resilience are essential for business growth, with SMEs that establish strong partnerships likely to enhance their long-term business value. However, forming global partnerships poses significant challenges for SMEs in developing countries, often hindered by limited government support for internationalization, insufficient knowledge of global markets, and restricted access to finance. Consequently, the emphasis on indicators such as competition and pressure from business partners, supply chain management and collaboration, and sustainability, while sidelining global engagement, suggests a strategic prioritization of bolstering local and immediate supply chain relationships over global integration. This approach is driven by the recognition that for SMEs, nurturing immediate collaborative networks and managing supply chain dynamics are paramount for achieving short-term readiness and adapting to Industry 4.0. This stance is reinforced by research that highlights the significance of supply chain integration and collaboration in enhancing operational efficiency and fostering innovation within the framework of Industry 4.0,

underscoring the tailored strategies SMEs must adopt to navigate the complexities of digital transformation effectively (Piccarozzi, Aquilani, and Gatti, 2018).(Junita et al., 2023).

6. Conclusion

In conclusion, this research addresses a crucial gap in SME-focused models to evaluate industry 4.0 readiness across awareness, organizational, technological and collaboration dimensions. The mixed methods model development and statistical validation undertaken enhance robustness and reliability for application among SMEs of varying maturity. The tool equips managers with data-driven insights on digitization capabilities to construct tailored roadmaps. Specifically, the dimensions pinpoint strengths, barriers and priorities to inject innovation for long-term success in the digital era.

The framework for Industry 4.0 readiness in SMEs represents a significant advancement in our understanding of how small and medium enterprises (SMEs) can effectively embrace technological advancements. By providing a structured approach, this framework enables researchers and practitioners to delve deeper into the intricate layers of technological adoption within SMEs. It emphasizes the pivotal role of various factors, such as industry awareness, managerial support, technological capabilities, customer-centric approaches, collaboration strategies, and global engagement, in shaping SMEs' readiness for Industry 4.0. Moreover, the framework underscores the interconnectedness of these organizational dimensions, highlighting how they collectively influence SMEs' preparedness for Industry 4.0 adoption. By offering such insights, the framework contributes to a more comprehensive understanding of the complex phenomenon surrounding SMEs' integration of Industry 4.0 technologies, thereby guiding future research endeavours and strategic initiatives aimed at fostering innovation and competitiveness within SME sectors.

Also, it provides invaluable practical guidance for small and medium enterprises (SMEs) aiming to bolster their preparedness for Industry 4.0 adoption. By systematically identifying key areas for improvement and strategic focus, the framework empowers SMEs to navigate the complexities of technological integration with clarity and purpose. Through its emphasis on critical factors such as industry awareness, managerial support, technological infrastructure, customer-centric innovation, and collaboration strategies, the framework equips SMEs with the necessary tools to prioritize investments and initiatives effectively. By addressing these identified indicators, SMEs can develop actionable plans tailored to their specific needs and circumstances, enabling them to harness the transformative potential of Industry 4.0 technologies. In doing so, SMEs can position themselves to thrive in today's dynamic and competitive business landscape, ensuring sustained relevance and success amidst rapid technological advancements.

Managerial Implications for SMEs is SME owners and managers can use the framework to assess their readiness for Industry 4.0 and pinpoint areas that need attention and investment. It stresses fostering innovation and learning to adapt to technology and market changes. Proactive leadership and planning are crucial for SMEs to navigate Industry 4.0's challenges and opportunities, ensuring their long-term growth and sustainability. For future research directions, it can validate and improve the framework through studies across different industries and regions. Investigating specific challenges faced by SMEs in adopting Industry 4.0, especially in resource-limited settings, can offer insights for policymakers and stakeholders. Exploring the role of policies and initiatives in facilitating SMEs' transition to Industry 4.0 can provide practical recommendations for fostering innovation and competitiveness.

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