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Identifying weaknesses and strengths of existing I4.0 Readiness Indices to enhance INDI 4.0

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Abstract
Indonesia has low Industry 4.0 (I4.0) readiness in ASEAN and has the INDI 4.0 Instrument (Indonesia Industry 4.0 Readiness Index), which is less comprehensive and accurate. An Initial survey confirmed that only 56.86% of respondents agreed that INDI 4.0 accurately measures readiness in the manufacturing industry. Unlike primary I4.0 indices, INDI 4.0 lacks comprehensive Industry 4.0 dimensions and characteristics, as many literature and other indices cover. This study aims to identify weaknesses and strengths of major I4.0 indices by comparing them to enhance INDI 4.0. This paper identified gaps in existing major I4.0 indices by scoping review method. However, each index contributes to increasing practicality, fulfilling latent needs, and expanding complementary perspectives in measuring readiness and adoption of I4.0 based on studies, viewpoints, uniqueness, and views of each. This study offered a more comprehensive perspective, especially from developing countries like Indonesia, with industries struggling to adopt I4.0 to fill loopholes in existing major indices that are generally from developed countries, so most companies in their study have advanced or implemented I4.0 and are too focused and too oriented on technology. The findings from this paper are expected to contribute to industry, practitioners, and academicians in increasing accuracy when measuring readiness toward adopting I4.0.

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INTRODUCTION

Indonesia has the lowest rank in the timeline for launching an I4.0 Initiatives policy in Southeast Asia, compared to Singapore, Thailand, Malaysia, and Vietnam [1]. It reflects the readiness level toward I4.0. By using INDI 4.0 (Indonesia Industry 4.0 Readiness Index) to measure I4.0 readiness in Indonesia, an initial report showed that Indonesia's manufacturer obtained a low-level score with a total average of 2,002 (scale from 0 to 4) [2]. On the other hand, Indonesia spends the most negligible expenses on ICT (information communication technology) compared to ASEAN countries like Singapore, Thailand, and Malaysia, with only 1.3% of the Gross Domestic Product (GDP). It reflects Indonesia at a low level of I4.0 readiness toward I4.0.

INDI 4.0 has five main dimensions: Management and organization, People and Culture, Technology, Products and processes, and Plant operations. Each dimension is represented by 4 to five simple multiple-choice questions. For example, the Dimension of Factory operation consists of only four simple questions: where data is stored, what technologies are applied in logistics, the percentage of the automation process, and what system is applied in maintenance. Each dimension is represented by one specific multiple-choice question. In any literature review, defining these dimensions, like smart logistics, smart maintenance, and automation process, needs to be determined by more than one statement covered by the multiple-choice question above and is doubtfully accurate in reflecting each dimension. It lacks complete accuracy.

Some significant sources initiating for I4.0 recommend expanding perspectives and points of view, including reviewing and completing existing I4.0 indices [3]. Most existing indices came from developed countries and are also used in developing countries, which is different in starting points in adopting I4.0. In this study, the choice of dimensions needs to consider the perspectives of industrial players in developing countries, like Indonesia, who experience unique obstacles and challenges. It is vital to note that several Industry 4.0 readiness models concerning existing Industry 4.0 readiness models, including INDI 4.0, have some critical gaps and problems [4].

There are many views and analyses that the existing I4.0 readiness in Indonesia is less accurate in measuring the readiness to adopt Industry 4.0 [5]. In a Focus Group Discussion initiated by the researcher and attended by academics, practitioners, and industries planning to adopt I4.0, many feedbacks concluded that INDI 4.0 measuring I4.0 readiness of factory operation aspect with only closed and multiple-choice questions needs more comprehensiveness and accuracy. It was confirmed by an initial survey of the industries involved in adopting Industry 4.0 in this study.

The survey result indicated an assessment of INDI 4.0 capturing I4.0 readiness in the factory operation aspect. Only 56.86% of respondents agreed that the current INDI 4.0 assessment was accurate. Also, in the second survey, only 42.11% of respondents answered that INDI 4.0 represent I4.0 readiness. It indicated a low percentage and a clue that this concern requires improvement.

This study compares major I4.0 indices, including INDI 4.0, concerning INDI 4.0 to capture a company level of I4.0 readiness with very few I4.0 readiness characteristics. When it goes to the scope of the question, it is too narrow and specific, contrasting with other indices, such as SIMMI 4.0, RAMI 4.0, DREAMY, and others.

SIMMI 4.0

SIMMI 4.0 means System Integration Maturity Model I4.0. Christian Leyh and Katja Bley from Technische Universitat Dresden – Germany, proposed this index consists of five dimensions in 2017 [6][7].

Several countries have widely adopted it, and it is also referred to in many scientific papers. The dimensions in SIMMI 4.0 consist of the following;

a. Company information
b. Vertical integration
c. Horizontal integration
d. Digital Product Development
e. Cross-sectional technology criteria

The five dimensions above comprise fifteen open questions.

DREAMY

The Digital Readiness Assessment Maturity Model (DREAMY) was developed by Anna De Carolis, Marco Macchi, Elisa Negri, and Sergio Terzic in 2017. It is created by referring to the principles of the CMMI (Capability Maturity Model Integration) platforms.

This model is introduced with two primary purposes [8][9]: conducting a manufacturing company's current digital readiness assessment, identifying its strengths and weaknesses for the applied technology and organizational processes, and Identifying the opportunities and strengths for companies aiming to overcome their weaknesses.

This assessment model proposes a model application tool structured around the process areas and aims at assessing the company's capabilities according to the identified analysis dimensions in digital transformation. Each question is connected to standard normative answers structured according to an increasing level of maturity.

The following are the five-scale digital readiness maturity levels. Level 1 is 'initial', where the process is poorly controlled and reactive. Level 2 is 'managed'; it means partially planned. Level 3 is 'defined,' which is defined as planning and implementing good practices. Level 4 is 'integrated and Interoperable.' It means integrated into several applications and information exchanges and is fully planned and executed. Level 5 is 'digital-orientated' with a solid technology infrastructure and potential growth [10].

This model's structural areas are split into organizational processes, such as Design and Engineering, Production, Quality, Maintenance, and Logistics. They can be assessed independently and tailored per the organization's needs. The Dimensions of DREAMY as the objects of assessment comprise Process, Monitoring and Control, Technology, and Organization [11, 12, 10, 8].

RAMI 4.0

Germany has another I.4.0 index, namely Reference Architectural Model for I4.0 (RAMI 4.0), developed by Plattform Industrie 4.0, one of the world's largest I4.0 networks [13][14]. Platform I4.0 is an organization that was officially launched at the Hanover Fair in 2013. This organization coordinates the transition into the digital economy in industry and science to keep Germany a leader in providing technologies and Production.

Nowadays, RAMI 4.0 has been formally acknowledged by crucial experts and respected associations as the reference architecture model that best embodies the key concepts and ethos of I4.0 [15][16]. RAMI 4.0 is the I4.0 index designed in service-oriented architecture by combining all elements, information technology, and components in a layer and life cycle model, as shown in Figure 1 [14]. This model breaks down complex processes into easy-to-grasp packages, including data privacy and information technology security.

International Electrotechnical Commission (IEC) 62890 is an international standard principle that applies to various industrial sectors. This standard comprises the fundamental tenets for the life-cycle management of systems and components used for industrial-process measurement, control, and automation. IEC62262 is a standard for degrees of protection provided by enclosures for electrical equipment against external mechanical impacts, and IEC61512 is a standard for Batch Control. These standards are the platform for the frame and constraint for the cross-hierarchy level and are applied in RAMI 4.0 as a clear border that shall be met at every level.

RAMI 4.0 introduced I4.0 as a transformation from Industry 3.0 with hardware-based structure and functions, hierarchy-based communication, and isolated products [14].

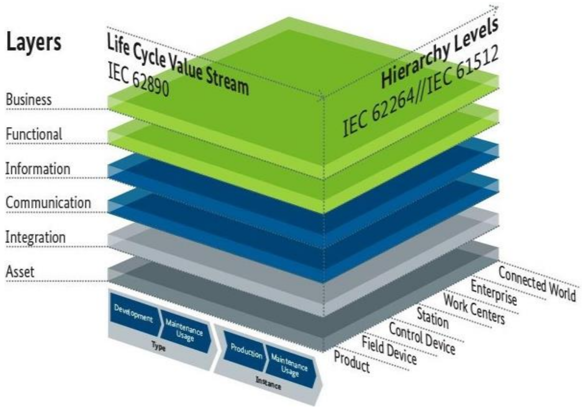

Figure 1. Structure of RAMI 4.0 [14]

RAMMI 4.0 embeds modern organization with I4.0 characteristics, which cover flexibility in systems and machines, function distribution throughout networks, the participation of all hierarchy levels, communication of all participants, and product being part of the network. This model is three-dimensional: Axis 1, 2, and 3 [15]. Axis 1 is the hierarchy in the factory (product, field device, control device, station, work centre, enterprise, connected word). It collaborates vertical integration in all enterprise levels, assets (all layers), and all supply chain units in horizontal integration. Interoperability and communication addressed all Internet of Things systems into all vertical pyramid hierarchies, from field to business level. RAMI 4.0 ensures communication in this complex system through administration cells that can be part of each field device, station, and work centre.

Axis 2 is the product life-cycle (development, maintenance usage, Production, maintenance usage). RAMI 4.0 provides a hierarchy levels axis from the first to sixth layers (asset, integration, communication, information, functional, and business) for mapping functionalities and responsibilities in implementing the I4.0. This hierarchy involves only the practical assignments within the model. The highest-ranking layer, the business layer, connects the organization to the outside world through international standards IEC 61512 and IEC 622647 (Industrial process measurement and control). This global standard is a reference to guide the organization in adapting to the outer world.

Axis 3 is the layer Architecture of RAMI 4.0 (asset, integration, communication, information, functional. business). RAMI 4.0 model is product-oriented, and the product itself is traceable. RAMI keeps track of the product life-cycle and the product value- -stream.

IMPULS

The IMPULS Foundation initiated the IMPULS Industry 4.0 Readiness Index. This foundation is an affiliate of the German Engineering Federation (VDMA), IW Consultant (a subsidiary of the Cologne Institute for Economic Research), the Institute for Industrial Management (FIR) at RWTH Aachen University and several leading industry representatives in Germany. The IMPULS Industry 4.0 Readiness Index model was introduced in 2015 and initially intended to focus on the mechanical engineering segment [10]. Here is the Framework of IMPULS Industry 4.0 Readiness in Figure 2.

Figure 2. Framework of IMPULS Industry 4.0 Readiness [17]

As shown in Figure 2, IMPULS comprises six dimensions that consisting of [18, 19, 20];

a. Strategy and organization (three sub-dimensions: strategy, investment, and innovation management)
b. Smart factory (four sub-dimensions: digital modelling, equipment infrastructure, data usage, and IT systems)
c. Smart operations (four sub-dimensions: information sharing, autonomous processes, security, and cloud usage)
d. Smart products (two sub-dimensions: technology add-on functionalities and data Data analytics in the usage phase).
e. Data-driven services (three sub-dimensions: data sharing, revenue sharing, and other data-driven services)
f. Employees consist of two sub-dimensions: employee skill sets and skill acquisition.

In Levelling of I4.0 readiness, five levels in classification reflect how ready an organization is to adopt I4.0 [10]. *Level 0 is Outsider*, meaning no indication or qualification in adopting I4.0. *Level 1 is* Intermediate, owning a strategy and orientation toward Industry 4.0. Level 2 is utilizing its resources toward the I4.0 transformation and being open to change and innovation. Level 3 is experienced, indicating that the organization has established an Industry 4.0 strategy, financial plan, IT systems, interconnection in critical areas, equipment, devices, and upgradable infrastructure to anticipate future technology. Level 4 is 'expert' that indicates in progress already using the Industry 4.0 strategy, directing resources and investment to innovate and adopt technology towards I4.0..0 transformation process to all organizational functions and operations.

The last one is Level 5, *Top Performer* level. The organization has implemented Industry 4.0 and has developed a comprehensive innovation management towards I4.0 leadership. On the other hand, the Data life-cycle drives decisions at every level with vertically and horizontally integrated systems. Operation in the organization is already run autonomously with autonomous processes. This level indicates that the organization is expertise in all critical areas of I4.0 transformation and can move forward.

Some I4.0 indices from some countries

Each country has a readiness index of I4.0. Generally refer to existing main I4.0 indices, such as SIMMI 4.0, RAMI 4.0, DREAMY, IMPULS, and so on, perhaps with some modifications suggested by consultants according to their unique circumstances, culture, and particular context. Some even followed the example of Germany with its Acatech through a Benchmarking approach.

Acatech (Akademie der Technikwissenschaften – Deutsche / German Academy of Science and Engineering) is the I4.0 index in Germany as one of the initial model pioneers of the I4.0 index. There are four core elements of structural areas in the Acatech Index: Organizational structure, Resources and Technology, Culture, and Information system.

Acatech comprises a two-stage maturity model, Digitalization level and Industry 4.0 level, in which the attainment of each development stage delivers additional benefits. The Digitalization level contains Level 1: Computerization and Level 2: Connectivity. I4.0 level consists of Level 3: Visibility, Level 4: Transparency, Level 5: Predictive capacity, and Level 6: Adaptability.

The higher the level, the higher the I4.0 adoption rate. Continuous improvement at this level means continuous adaptation, allowing the organization to delegate certain decisions autonomously to a computer system. It can respond to the dynamics of change, business adaptation, environment, and circumstances as quickly as possible. The objective of this level is achieved when advanced systems transform the data from the multi-sources into helpful information to support decisions with the shortest possible time and most accuracy.

The other country, like Singapore, has an I4.0 readiness index, namely, the Singapore Smart Industry Readiness Index. It is a tool that covers three core elements of I4.0: technology, process, and organization. The first, technology, consists of three pillars (Automation, Connectivity, and Intelligence). Secondly, Organizations consist of two pillars (Talent readiness, structure & management), and the last one is the process, which consists of three pillars (Operations, Supply Chain, and Product Cycle). These pillars above are then broken down into sixteen dimensions accompanied by the level of I4.0 readiness.

Not all of the I4.0 Indices have complete and perfect dimensions. It looks complementary depending on the context, conditions and needs in implementing I4.0, the background for forming the I4.0 Index where they were born. All initiating sources for I4.0 recommend expanding perspectives and points of view, including reviewing and completing I4.0. This study does not possibly find gaps and overcome all the weaknesses of the existing I4.0 index, but it tries to find weaknesses and deficiencies to improve accuracy in assessment.

What needs to be underlined is that there is no existing literature, reference, or I4.0 index containing a complete and perfect instrument model that meets the needs of Industry 4.0 in preparing organizations to adopt I4.0 [7]. What needs to be done is to continue to carry out continuous exploration, research, and improvement in opening up the possibility of improvement in each instrument model. The I4.0 index instrument should be developed with more specific aspects of the system in detail, incorporating different viewpoints and enabling organizations to classify themselves fully in terms of Industry 4.0 adoption readiness requirements at all levels of the organization [7].

METHODS

This study uses an approach of scoping review to aim for research objectives, as presented in Figure 3. It starts by identifying research questions and relevant studies and collating, summarizing, and reporting the study results [21]. In this method, the starting point is to identify the research question as a guide for the research's objectives: what are the loopholes of some existing major I4.0 readiness indices to enhance INDI 4.0?

Secondly, in Figure 3, identifying relevant studies about Industry 4.0, then selecting papers focusing on I4.0 dimensions and characteristics (Identifying 72 relevant articles, selecting the most pertinent ten articles). The next step is to apply to all the citations to determine their relevance. Furthermore, mapping the data from selected papers by analyzing author(s), year of publication, study location, intervention type, comparator (if any), duration of the intervention,

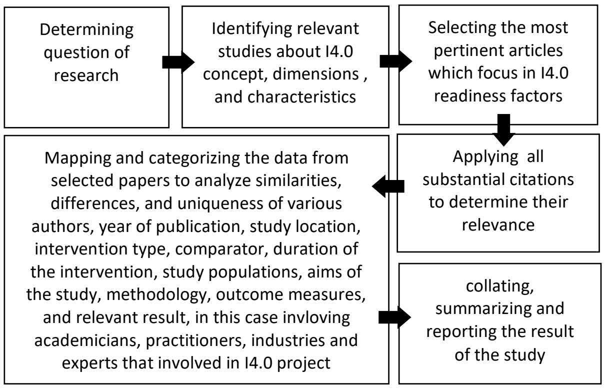

Figure 3. Scoping review method [21]

study populations, aims of the study, methodology, outcome measures, and relevant results. The last step is to collate, summarize and report the result of the study.

The final stage of this study is to identify loopholes in the study, especially in existing I4.0 indices relying on kinds of literature review and focus group discussion (FGD) consultation with qualified experts, practitioners, and academics in comparing the I4.0 readiness index. It is a standpoint to improve the accuracy of I4.0 readiness in an industry. The above study steps are a scoping review approach from identifying research questions and relevant study, finally collating, summarizing, and reporting the study result [21].

Table 1. Pillars of Prominent I4.0 Index

Dimensions	A	B	C	D	F	G	H	I	FREQ
Organization		X	X	X	X	X	X	X	7
Technology	X	X	X	X		X	X		6
Process		X	X		X		X	X	5
Factory operation					X	X		X	3
Smart product					X	X		X	3
People/Talent					X	X		X	3
Vertical Integration	X		X				*		2
Strategy					X			X	2
Horizontal integration	X		X				*		2
Culture				X		X			2
Information system				X					1
Resources				X					1
Communication			X						1
Digital Development	X								1
Product Life-cycle			X				*		1
Data Life-cycle					X			X	1
Asset			X						1
Information			X						1
Monitoring and control		X							1
Intelligent									0
Supply Chain							*		0
Connectivity							*		0
Automation							*		0

Note:
A = SIMMI 4.0, B = DREAMY, C = RAMI 4.0,
D = ACATECH, E = IMPULS, **F = INDI 4.0**,
G = Singapore Smart Index, H = Malaysia 4 FWRD

RESULTS AND DISCUSSION

The difference in dimensions of the main I4.0 Readiness Indices

In general, most I4.0 indices are made similarly: the steps to develop the I4.0 readiness index, level of I4.0 readiness, dimensions or aspects covered by the respective I4.0 index, technology element in I4.0, and how in levelling of readiness. They seem to use the same playbook in developing the I4.0 index. However, there are differences in measuring, dimensions scope, and detailed instruments, such as the dimension scopes in Table 1.

Weakness & Strengths in Major Indices

Table 1 shows the differences in the dimensions used by several main I4.0 Indexes widely used as references, also included in column F for INDI 4.0 as an instrument of I4.0 readiness used in Indonesia. From several main references in the literature review, Table 2 and Table 3 are the weaknesses and strengths of the analysis of the exploration of several main I4.0 Indices confirmed by FGD consisting of experts, practitioners, and academicians involved in I4.0 project adoption.

Table 2. Weakness of Exiting I4.0 Index

I4.0 INDEX	WEAKNESS
SIMMI 4.0	•Too focused on information technology [7] •The scope of the assessment dimensions is too narrow to focus on technology, digitization, and integration. •The organizations surveyed in the SIMMI 4.0 research are companies that have implemented and are currently implementing Industry 4.0 projects. However, a broader perspective is needed in implementing I4.0, for example, for companies that have not implemented I4.0 at all [7] •The development of SIMMI 4.0 has not been fully completed [7] •There has been no development of other system-specific aspects in detail and has not combined different viewpoints[7] •Not yet based on the company's application of a concrete model [6]. •SIMMI 4.0 has not proven its practicality and usefulness in a corporate environment [6] •A mapping of SIMMI 4.0 would be necessary to combine different points of view. •Different maturity level assignments and dimensions between these models should be developed to enable companies to fully classify themselves in terms of Industry 4.0 requirements at all levels of their enterprise. [7]
DREAMY	•Has not yet identified the prerequisites for the implementation of I4.0 supporting technology to increase the company's readiness level [22] •Using Questions with normative answers •Assessment methods Interview/case study, not self-assessment[3] •Dreamy requires competent analysts to be utilized [12]. •Dreamy requires time to be utilized for the analyzed company [12]. •Dreamy must be continuously updated to reduce the potential risk of obsolescence [12].
RAMI 4.0	•RAMI 4.0 is focused on product development and production scenarios within the environment of an Industry 4.0 enterprise [15] •The hierarchy in RAMI 4.0 structure does not describe the implementation, only functional assignments within the model [15] •RAMI 4.0 adapts the IEC 622647 and IEC 61512 standards, adding a connected world, field device, and product to suit Industry 4.0 applications. •RAMI 4.0 is heavily focused on the information technology involved in an Industry 4.0 application •RAMI 4.0 is heavily focused on the information technology involved in an Industry 4.0 application [15].
ACATECH	•Focus only on the technological perspective [23] •The basic level in Acatech is computerization. In contrast, many industries in even lower levels than computerization •Acatech seems to tend to describe the broad integration of information and communication technology in the manufacturing (Production) industry [23] •The main purpose is for companies to master digital transformation in all related business units involved, not touching other supporting factors related to sustainability in the process towards I4.0 [23] •Lacking specific when applied to different industries, there must be an identification of varying treatment factors according to industry characteristics. •Acatech requires further validation to be carried out to hide the special features of various sectors and types of industries in adopting I4.0

Table 3. Strength of Exiting I4.0 Index

I4.0 INDEX	STRENGTH
SIMMI 4.0	• Addressing or closing the gap with the wrong self-assessment, which focusing the digitization level [7]. • Providing an accurate assessment of a company's IT system landscape readiness in Industry 4.0. • Providing support for enterprises in terms of a toolset to classify and assess their IT system landscape in the context of the Industry 4.0 requirements • SIMMI 4.0 is a strong model to asses an organization with IT, digital, and technology orientation
DREAMY	• Dreamy is a solid model, valid for different manufacturing applications, developed with certified scientific methods. • Dreamy provides structured and consolidated knowledge • Dreamy was developed as an academic activity considering scientific literature and methodology and involving many experts
RAMI 4.0	• RAMI 4.0 is a three-dimensional map showing how to approach the issue of Industrie 4.0 in an industry hierarchy structure [14]. • RAMI 4.0 ensures that all participants involved in Industrie 4.0 discussions understand each other because involving Participants interact across hierarchy levels [14]. • This model is a service-oriented architecture combining all elements and IT components in a layer and life cycle model [14]. • RAMI 4.0 breaks down complex processes into easy-to-grasp packages, including data privacy and IT security [14]. • This model has flexible systems and machines; functions are distributed throughout the network, and communication among all participants. • The RAMI 4.0 model goes beyond pure Industry 4.0 system modelling and incorporates manufacturing and logistics aspects [15].
ACATECH	• Acatech includes organizational structure culture besides technology or information systems and resources as a comprehensive approach to adopting I4.0 [24] • The ultimate goal is not about adopting advanced technology but reaching sustainability to become a learning, agile organization capable of continuous, agile adaptation to a changing environment [24] • Acatech provides clear and detailed guidance and presents six consecutive development levels (computerization-connectivity-visibility-transparency-predictive capacity-adaptability) for four key areas of every company (organization, culture, information system, resources, and addressed to organization function areas (development, Production, logistics, services, marketing & sales) • Providing clear benefits for each level stage delivers additional benefits to the company. • The index can be used to develop a digital roadmap tailored to each company's needs to help them master the digital transformation across all involved relevant business units.
IMPULS	• IMPULS provides the weight factors by asking the survey companies to score each dimension's importance. It depends on company priorities and characteristics [25][20]. • IMPULS is built based on a comprehensive dataset and details about dimensions items, including the approach to assessment [18] • The model is scientifically well-grounded, and its structure and results are explained transparently [18] • IMPULS clearly provides minimum requirements at every level of maturity [17]

Loopholes and Gaps

Despite no existing literature, reference, or I4.0 index containing a complete and perfect instrument model that meets the needs of Industry 4.0, this study follows the recommendations and suggestions from previous research to fill the gaps as the loopholes from existing I4.0 indices such as

a. I4.0 Initiators of existing indices are generally from developed countries, so the cases that become examples of studies in the companies studied are only companies that have implemented and carried out Industry 4 projects [7], including INDI 4.0 as an outcome from a team accompanied by AT Kearney and adopted from Germany
b. The research requires a different perspective that this study offers, for example, from industries striving towards the transformation of Industry 4.0, especially from developing countries [7] like Indonesia.
c. Some existing research is too focused and too oriented on technology [7]
d. Some major papers recommended using different tools, considering a more diverse number of dimensions, support, and indicators to maintain the integrity of the developed model [22]. It is what this study is conducted to comply with it.

Room for Improvement

This study does not possibly find gaps and overcome all the weaknesses of the existing I4.0 index, but it tries to find weaknesses and deficiencies in general that the I4.0 Index currently owns, including INDI 4.0;

a. Each I4.0 index has its dimension to measure I4.0 readiness, complementing each other. It depends on background, context, goals, and many other things in putting dimensions at each index I4.0. The typical storyline and principles on the main dimensions in index I4.0 are characteristics and significant factors influencing the adoption and readiness of I4.0. This study found that INDI 4.0 captures very few characteristics, principles, and dimensions in measuring I4.0 readiness. It lacks accuracy and is less comprehensive in measuring I4.0 readiness.
b. All the main reference indices, such as Acatech, IMPULS, RAMI 4.0, and others, were born in developed countries. Their case studies are in industrial organizations that have relatively implemented Industry 4.0. It is recognized, and they recommend the need for perspective from struggling industrial organizations that want to implement Industry 4.0, for example, industry in developing countries like Indonesia.
c. The primary reference for index I4.0 generally comes from Developed Countries, which determine the level of readiness to adopt I4.0 based on their factual industry conditions. Of course, they have different starting points with developing countries, so readiness level & classification, instrument, dimensions, weight, and model must be adapted to the organization where it exists.
d. Almost all literature states that there is no perfect I4.0 index. They expect continuous development to get various perspectives from various points of view. This study focuses on measuring the I4.0 readiness index in Indonesia, which is currently using INDI 4.0, which is considered less accurate.
e. Based on its dimension, Some I4.0 indices focus on technology and IT, for example, SIMMI 4.0, IMPULS, RAMI 4.0, and IMPULS. On the other hand, the other begins to shift considering organizational, management, and even cultural factors such as Acatech, Singapore I4.0 Smart index, and Dreamy, even with a portion of their version that is familiar with innovation and new technology as a developed country. The I4.0 index dimension has not emerged from actors who have not and are struggling to implement I4.0.
f. Not all of the I4.0 Indices have complete and perfect dimensions. It looks complementary depending on the context, conditions and needs in implementing I4.0, the background for forming the I4.0 Index where they were born. All initiating sources for I4.0 recommend expanding perspectives and points of view, including reviewing and completing I4.0. In this study, the choice of dimensions needs to consider the perspectives of industrial players in developing countries who experience natural obstacles and challenges.
g. Based on how to measure Some I4.0 indices directly measure the organization as a whole (IMPULS, Singapore I4.0 Smart Index, TUV), it requires a smaller team who profoundly understands I4.0. On the other hand, the other I4.0 indices measure respective function areas such as Production, logistics, marketing, sales, services, and development (Acatech, SIMMI 4.0, Dreamy). It requires a bigger team that involves cross-department.

In the case of ASEAN Countries, the Singapore Industry Smart Index and Malaysia 4FWRD appear similar in dimensions and measurement approach. They combine approaches from TUV, Dreamy, and SIMMI 4.0. Singapore defines three blocks (process, technology, and organization), divides them into eight pillars, and breaks them down into sixteen dimensions. In each dimension, Singapore clearly defines each level of readiness. So, organizations just have to work out where they are concerning the level of preparedness I4.0 that has been provided. Practically, it becomes a challenge when sub-organizations have different system readiness and fragmentation. Team agreement and specific calculations are required to infer measurement results accurately.

Then, from the loopholes and room for improvement in research gaps, this study identified a platform consisting of seven dimensions as part of this study to measure I4.0 readiness [26]. The seven dimensions of I4.0 consist of the following;

1. Management [27, 24, 28, 29, 30, 45, 32]
2. People [33, 24, 29, 34, 35, 36, 37]
3. Technology [38, 39, 22, 40 41, 24, 42, 43]
4. Data life-cycle [44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54]
5. I4.0 Design principles [39, 35, 55, 56]
6. Smart factory [44, 57, 58, 54, 44, 59, 60, 40]
7. Smart maintenance [45, 52, 44, 52, 61, 62, 63, 64]

This paper fills the gaps in several previous studies regarding comparative studies of several major I4.0 indices or the development of instruments to measure Industry 4.0 readiness, focusing on technological characteristics. [41], information system and technology [7], implementation of the existing I4.0 index [29, 34, 35], and the I4.0 comparison, which focuses on the degree of readiness [22]. The significant contribution of this paper is identifying the main weaknesses and strengths of major I4.0 indices that contribute to developing existing I4.0, especially developing countries like Indonesia, which should consider feedback from industries that are struggling to implement I4.0.

CONCLUSION

This paper provided the weaknesses and strengths by comparing the major I4.0 readiness indices to improve INDI 4.0. It came from a literature review and related documents on using I4.0 readiness indices, such as RAMI 4.0, SIMMI 4.0, DREAMY, IMPULS, and Acatech. This comparison result confirmed by the Focus Group Discussion comprises experts, academicians, practitioners, and industries involved in adopting the I4.0 project.

This comparison can give a clear overview through weaknesses and strengths of respective I4.0 index so users can address what elements or dimensions fit their organization. In addition, this study considers what has not been captured by the existing I4.0 indices, namely the needs or inputs that are really needed from industries that are struggling or have not yet implemented I4.0 but have the desire to adopt it, which are usually in developing countries. It is the expected contribution of this paper.

This paper cannot focus too much on general industry 4.0, not specific aspects or significant pillars of I4.0 in more detail, such as people, organization, technology, process, culture, data life-cycle, smart factory, I4.0 design principles, and important factors others and characteristics.

Future research related to adopting I4.0 shall not only be companies that have already implemented and conducted Industry 4.0 projects in a certain way but also cover other companies or beginners. This suggestion also came from I4.0 other prominent researchers like Leyh, Schaffer, Bley, and Bay. So, the research will have a more comprehensive perspective to capture obstacles, challenges, opportunities, and accurate strategies in adopting I4.0.

From a practical perspective, especially in national scope, this approach implies INDI 4.0 requires comprehensive review and evaluation while addressing its lack of accuracy in measuring I4.0 readiness. Other issues regarding INDI 4.0 dimensions, such as organization, management, people, culture, technology, product, and services, must also be addressed. As such, INDI 4.0 is a strategic issue in the national interest that needs more exploration from other researchers to complete future studies. It is important to review different and other vital dimensions affecting I4.0 readiness, possibly to complete deficiency, incompleteness, and loopholes to improve this research.

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