The Development of the Maturity Model to Assess the Smart Indonesia Manufacturing Companies 4.0 Readiness

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Abstract—**This study aims to propose a maturity model and related tools to assess the readiness of Indonesian smart manufacturing companies in dealing with industry 4.0. The development of this model uses a multi-mixed methodology, combining systematic literature study analysis, semi-structured interviews with experts, and surveys to validate the model. The maturity model built consisted of five dimensions and 34 sub-dimensions of analysis to evaluate the smart manufacturing companies' 4.0 readiness. The main dimensions of this model are Technology, Products and Services, Corporate Operations, Strategies and Organizations, and Human Resources. The model was then tested in 15 automotive component manufacturing companies in Indonesia where the results are presented in this paper. From the test results in the field shows that the maturity model built in its application in the field is quite easy to understand by the company so that it can be used independently to identify industry 4.0 readiness.**

Keywords: maturity model, industry 4.0, smart manufacturing companies' 4.0 readiness, automotive component manufacturing

I. INTRODUCTION

The information and communication technology (ICT) has been developed very fast in the last few decades and its integration into the manufacturing process has benefited the entire value chain and has led to a new era called the 4th industrial revolution [1]. Besides being expected to be able to manage the entire value chain in an agile and responsive way [2], the integration of ICT into the process of manufacture is also expected to be able to leverage industrial productivity, reduce production costs, and provide effective solutions to serve customers with quality, speed, and overall costs and benefits [1].

Technological advances have been the foundation of the four major industrial revolutions. The discovery of steam power enabled the first industrial revolution, while innovations in electric power catalyzed the second. In the same way, the next industrial revolution was supported by the emergence of an electronic control system and Information Technology (IT) that allowed companies to achieve a higher level of precision and efficiency through automation. The fourth industrial revolution is based on the use of new digital technologies, such as cloud computing, machine learning, and the Internet of Things (IoT), which have reorganized the classical hierarchical automation system to independently regulate cyber-physical production systems that enable flexible mass production customization and flexibility in total production [3].

The fourth industrial revolution, firstly initiated by the Government of German in 2013, has created a connected industrial landscape across broad boundaries where physical assets and equipment integrate with enterprise systems to enable constant and dynamic exchange and analysis of data. Besides, the internet and its complementary technologies function as the backbone for integrating physical objects, human actors, intelligent machines, production lines and processes beyond organizational boundaries to form new types of agile intelligence, networks, and value chains [3]. These virtual-physical systems, in turn, make the company more agile and agile. If in the previous industrial revolution era, the use of the latest technology in production technology is more focused on the efficiency of the manufacturing process in individual companies so that the concept of manufacturing automation is born, in the current era of the industrial revolution there are technological advances, especially this new ICT technology, giving birth to the concept of manufacturing collaboration to integrate the technology into manufacturing technology so that the focus of improving the efficiency of the manufacturing process covers the entire supply chain. In the future, integration and digital intelligence of the manufacturing process are expected to be able to increase the efficiency of the manufacturing process even more significantly. Therefore, integration needs to be done not only at the horizontal level (in all stakeholders in the whole value chain) but also at the vertical level (in the whole automation layer). Fully integrated and networked factories, machines, and products will then be able to act in an intelligent and partially autonomous way that requires minimal manual operation [1,3].

At present, the Government of Indonesia through the Ministry of Industry has formulated the "Making Indonesia 4.0" initiative to implement the Industry 4.0 roadmap and strategy in Indonesia [4]. Five main industrial sectors that were chosen early to implement this 4.0 industry, namely: the food and beverage industry, textiles and apparel, automotive, chemical, and electronics. Of course, for the successful implementation of the industry 4.0 roadmap and strategy in the

five industrial sectors, the initial step that must be taken is to assess the readiness of the industry 4.0 of companies in the five sectors.

Currently, to assess the industry's readiness and maturity 4.0, experts have compiled and developed many models of maturity assessment [2,5-7], including in this case, an Indonesia Industry assessment model 4.0 Readiness Index (INDI 4.0), a reference index for industry and government in rating the level of readiness of the industry to transform towards industry 4.0 in Indonesia. Some of the models found in the literature and have been published were IMPULS [8,9], An Industry 4.0 readiness assessment tool [10], The Singapore Smart Industry Readiness Index [11], Industry 4.0 Maturity Model [2], and Industry 4.0-MM [6]. Lichtblau et al. [8] and IMPULS [9] is a model for evaluating industry readiness 4.0, consisting of 6 dimensions and 18 assessment sub-dimensions assessed with 5 levels of assessment criteria. Model Agca [10] consists of 5 dimensions and 37 assessment sub-dimensions and is assessed with 4 levels of assessment criteria. Model Singapore Economic Development Board [11] is a model for assessing the readiness of the Singapore 4.0 manufacturing company's industry, consisting of 3 building blocks, 8 pillars, and 16 valuation dimensions, with 5 levels of assessment criteria. Model Schumacher et al. developed to assess the maturity of industry 4.0 [2], consisting of 9 dimensions and 62 assessment items with 5 levels of assessment criteria. Model Ebru [6] consisting of 5 dimensions of industrial capability. Chonsawat and Sopadang stated that the IMPULS model and The University of Warwick model are two models that are quite popular and become a reference for identifying key factors for preparation for entering the industrial era 4.0 [5].

This paper is the result of a study that aims to propose a maturity model and related tools that are systematically used to assess the readiness and maturity of industry 4.0 in manufacturing companies associated with its industry vision 4.0. Maturity models are developed by combining scientific and practical approaches based on previously developed models.

From the results of measurements with this model, it is hoped that data will be obtained about the state of industry readiness and maturity 4.0 from smart manufacturing companies. With this model, it also allows companies to practically evaluate the maturity of Industry 4.0 on their own and reflect compliance with its current strategy.

II. RESEARCH METHODS

The research used a multi-mix methodology, carried out by systematic analysis of literature studies, interviews with practitioners and experts, and preliminary surveys to companies. Broadly speaking, the stages of development of this model include three stages of adopting [2].

The first stage is to conduct literature studies and interviews with experts and practitioners to get a complete understanding of the fourth industrial revolution domain. Literature studies are carried out by evaluating and analyzing existing Industry 4.0 maturity models, while semi-structured interviews with several experts are conducted to help find the basis for the problem and validation of the solution in assessing

the problem. At this stage also obtained relevant concepts for the fabrication of the model starting from the dimensions, the level of maturity, the mode of assessment, the mode of representation.

Maturity models to assess the readiness of smart manufacturing companies 4.0 developed and presented in this paper refer to Reference Architectural Model for Industry 4.0 (RAMI 4.0) [12] and models from Schumacher et al. [2], Rojko [3], Lichtblau et al. [8], IMPULS [9], Agca et al. 10] and Singapore Economic Development Board [11]. These models in addition to having a good scientific foundation and structure and the results are explained transparently, the models are based on data sets and have comprehensive details about the dimensions, items, and assessment approaches offered [2]. The RAMI 4.0 model is a service-oriented architecture, integrating all IT elements in three layers, namely product layers, which are layers that describe the factory hierarchy, development layers, layers that describe the product life cycle in an industry, and the asset (business) layers, layers that describe industrial architecture. In the IMPULS model, the dimensions of industry readiness assessment of 4.0 are smart factories, smart operations, smart products, data-driven services, workforce, and organizational strategy. The model Agca et al. [10] has an industry readiness assessment dimension 4.0, namely supply chains, manufacturing and operations, products and services, business models, legal considerations, and strategy and organization. The Index Assessment Model from Singapore consists of 3 pillars, namely: Technology pillar with dimensions of automation, connectivity, and intelligence, Process pillar consists of operating dimensions, supply chain, and product life cycle, the organization pillar consists of dimensions of workforce talent and structure dimensions and management. Model Agca et al. covers the dimensions of strategy, leadership, customers, products, operations, culture, workforce, governance, and technology [2]. Model Ebru includes the dimensions of Asset Management, Data Governance, Management Application, Process Transformation, and Organizational Alignment [6].

Based on a review of literature on industry 4.0 and models of industry maturity and readiness 4.0, industry maturity assessment model 4.0 to assess the readiness of manufacturing companies that are developed must at least be able to assess aspects of technology, products and services, company operating processes, strategies and organizations, and corporate human resources.

The second stage is to design a structural model that will be used to define the 4.0 manufacturing industry readiness and maturity. Based on the concepts that have been obtained, the entire model that is built is designed and defined starting from the dimensions, maturity items as well as the level of maturity and its characteristics. The model built consists of five dimensions of analysis, namely: 1) Technology, 2) Physical Products and Services, 3) Company Operational Processes, 4) Strategies and Organizations, and 5) Human Resources, covering 34 maturity items which are grouped into these five dimensions, as can be seen in table 1.

TABLE I. DIMENSION AND ITEM THE MATURITY AND READINESS 4.0 MODELS

Dimensions	Sub Dimensions
Technology	Automation, Equipment readiness for I4.0, Machine integration & interoperability, Operation data collection, IT & data security, IT system support, Processing & analysis capability.
Product and Services	Product customization, Data-driven services, Digital features of products, Level of product data usage.
Company Operations	Vertical integration, Horizontal integration, Share of data used, Supply chain integration, Integration to CPS, Supply chain visibility, Supply chain flexibility, Integrated product lifecycle, Digital modeling, Data usage, Autonomous process.
Strategy and Organization	Degree of strategy implementation I4.0, Strategy & management I4.0, Collaboration, Innovation management, Investment strategy I4.0, Organization structure, Team leadership, Teamwork.
Human Resources Capability	People's capability, Leadership competency, Learning process, Adaptation process.

Source: data processing results, 2019

The third stage is the conversion of the model into a practical tool that can be used and conceptualization of adequate media for distribution. After completion of this model, it was tested on several automotive component manufacturing companies to validate for real-life applications and gather feedback for further model improvements.

Assessment and evaluation of sub-dimensions of the maturity and readiness assessment model of the 4.0 smart manufacturing companies that have been built are carried out using a set of indicators with an ordinal scale related to qualitative characteristics that will be used as a reference in evaluating. Criteria for evaluating each sub-dimension consist of six levels of maturity where level 0 represents the lowest attribute that supports the fourth industrial concept for the company and level 5 denotes the highest state (state of the art) of the required attributes. In general, the assessment of each sub-dimension for Level 0 (not ready) shows companies at this level are not ready or do not meet the requirements for Industry 4.0, Level 1 (beginners), companies at this level are involved in Industry 4.0 through pilot initiatives in various departments and investments in one area, Level 2 (intermediate), companies at this level have incorporated Industry 4.0 into their strategic orientation. Level 3 (experienced), companies at this level have formulated industry strategy 4.0 and implemented in several areas of the organization. Level 4 (expert), companies at this level have used industry 4.0 strategy, implemented in most areas of the organization and monitored it with appropriate indicators. Level 5 (top performer), companies at this level have implemented the Industry 4.0 strategy and regularly monitor the implementation condition of other projects.

The six levels of readiness can be grouped into three types, namely newcomers, learners, and leaders in Industry 4.0, which make it possible to summarize results better. This grouping also makes it easy to draw conclusions about progress and conditions related to industry 4.0 and identify specific action items based on the level of implementation. Newcomers (level 0 and level 1) include companies that do nothing or deal very little with Industry 4.0, Learners (level 2) state names for companies that are at level 2 and therefore have taken their first steps in implementing Industry 4.0, and Leaders (level 3 and

higher) include companies that have reached at least level 3 in the readiness model. They are well on their way to implementing Industry 4.0.

III. RESULTS

The following are the results obtained from case studies of 15 Indonesian automotive component companies with several employees between 20 - 99 people who were assessed for their readiness in facing industry 4.0 using the maturity and readiness model that had been built previously.

Retrieval of research data is done by surveying the company. Before the survey was conducted, the researcher sent this industry appraisal 4.0 questionnaires to the company by e-mail making it possible for companies to study this appraisal questionnaire and be able to identify their own company's internal situation based on the questionnaire sent. Furthermore, the researcher is assisted with the Surveyor collected data together with the manager or person appointed by the company to conduct an independent assessment to fill out the industry maturity and readiness questionnaire 4.0.
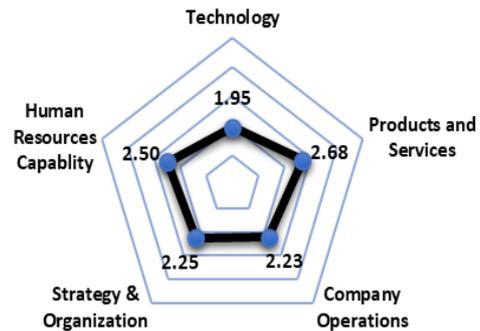

Fig. 1. Overall Industry 4.0 readiness level.

Figure 1 shows the level of industry maturity and readiness of 4.0 manufacturing companies visualized in the form of radar charts using a model that has been built. Based on this model, the average company readiness index assessed is 2.32.

Figure 2 shows the survey results that identified readiness measurements based on the dimensions of assessment. From fig. 2 shows that in the dimensions of products and services 13.33% of companies at the beginner level, 46.67% at the intermediate level, 33.33% at the experience level, and 6.67% at the expert level. In terms of technology, 6.67% of companies at the outsider level, 53.33% at the beginner level, 26.67% at the intermediate level, 6.67% at the experience level, and 6.67% at the expert level.
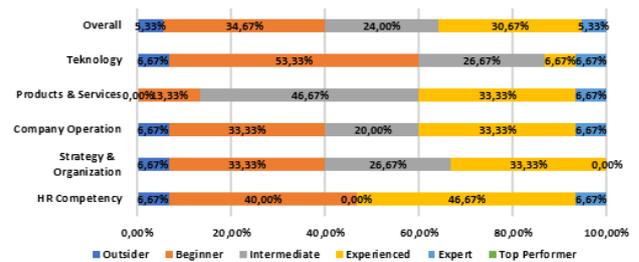

Fig. 2. Industry 4.0 readiness measurement.

Figure 3 shows the result of readiness measurement by the type of company. From fig. 3 shows that 40% of the companies at newcomers, 24% at learners, and 36% at a leader in Industry 4.0
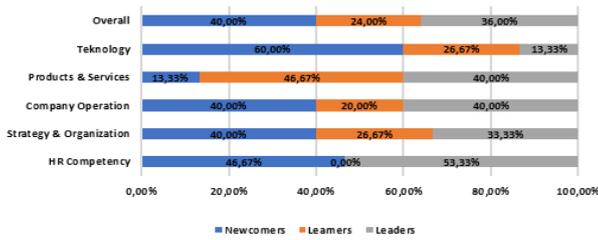

Fig. 3. Industry 4.0 Readiness Measurement by type of company.

To gain an understanding of the overall model, detailed measurement of the dimensions of the Technology, Products and Services, Company Operations, Strategy and Organization, and Human Resources Capability, the company independently assesses each maturity and readiness sub-dimension from level 0 up to level 5. Fig. 4 presents the radar graph of the results of the assessment of the Technology sub-dimensions. From the result, the average of the Technology sub-dimensions' readiness index assessed is 1.95.
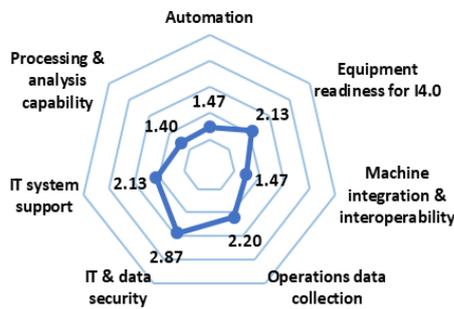
Fig. 4. Average technology readiness level.

Figure 5 is a visualization of a radar chart of the results of the company's self-assessment for sub-dimensions of Products and Services. Four sub-dimensions are assessed. In general, the level of industry readiness of 4.0 companies in the Product and Service sub-dimensions has an average index value of 2.68.
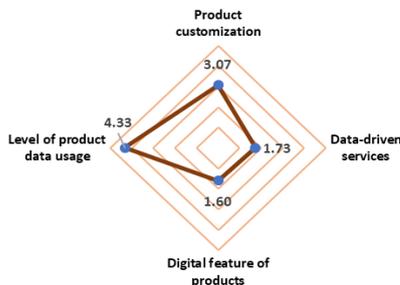

Fig. 5. Average product & services readiness level.

Figure 6 shows the visualization of a radar chart of the results of the company's self-assessment for sub-dimensions of the Company's Operations. In general, the company considers

that the level of industry 4.0 readiness in the sub-dimensions of the Company's operations has an average index value of 2.23.
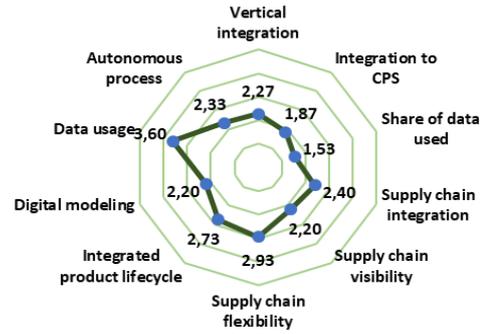

Fig. 6. Average company operations readiness level.

Figure 8 shows a radar chart of the results of an independent sub-dimension evaluation of Strategy and Organization conducted by the company. In general, companies consider that the level of industry readiness of 4.0 companies for Strategy and Organization sub-dimensions has an average index value of 2.25.
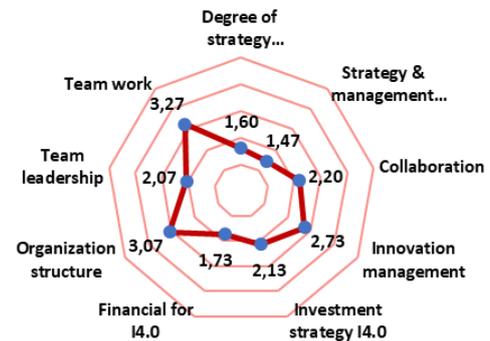
Fig. 7. Average company operations readiness level.
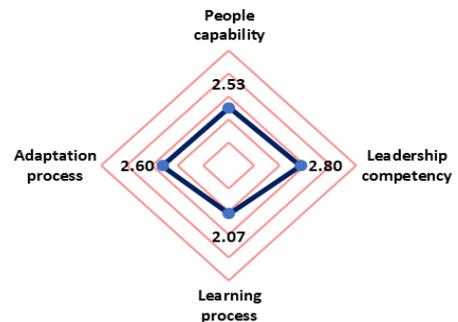
Fig. 8. Average company operations readiness level.

Figure 8 shows a radar graph independently from the Human Resources sub-dimension assessment conducted by the company. In general, the company considers that the average readiness index value of this dimension is 2.50.

IV. DISCUSSION

The maturity model that was built to assess the readiness of the industry 4.0 Indonesian smart manufacturing companies

consists of 5 dimensions of analysis and 34 sub-dimensions. In its application, the model is quite easy to understand by companies in the field so that it can be used independently to assess the readiness of industry 4.0 companies.

From the results of the assessment conducted in 15 companies, it was found that the average industry readiness assessment index 4.0 for automotive component companies is 2.37. This average index is at level 2 (intermediate) which means that in general automotive component companies have applied Industry 4.0 to their strategic focus. This company is included in the category of Learners and the company has taken the first step to start implementing industry 4.0. A more detailed index value for each dimension is obtained that for the Technology dimension is at level 2 (intermediate) with the readiest products and services (2.68) and technology being the last ready (1.95). For the product and service dimensions with the data usage level sub-dimension has the largest average index value (4.33), while the digital product sub-dimension features the lowest (1.60). For Operating Dimensions, the company is at level 3 (experience). The highest average value of the Company's Operations sub-dimension is obtained from the operational data usage sub-dimension with an average value of 3.60, while the average index value is comparable to the dimensions of 1.53. The Strategy and Organization dimension are at level 2 (intermediate) with the largest average index value for the Team Work sub-dimension of 3.27, while the lowest is the strategy and management sub-dimension I4.0 of 1.47. For the Human Resources dimension, the level of maturity is at level 2 (intermediate). The average value of the largest index sub-dimension is the Leadership Competence sub-dimension 2.81, while the average partial index value is the Learning Process 2.07.

V. CONCLUSION

This paper presents the results of developing the industry maturity model 4.0 to assess the readiness of smart manufacturing companies 4.0. Based on the results of the study conducted, the developed industry 4.0 model maturity consists of 5 main dimensions and 34 assessment dimensions. The five main dimensions are Technology, Products and Services, Company Operations, Strategy and Organization, and Human Resources Capability. Model development is carried out using a multi-mix methodology beginning with a systematic literature study by tracing publication data on industry maturity and readiness models that have been developed previously. To complete the understanding and development of semi-structured interview models with experts, a preliminary survey in the industry was carried out to validate the model.

The model was then tested in automotive component manufacturing companies in Indonesia, where 15 cases of automotive component companies with some workers between 20 and 99 are presented in this paper. The average value of the industry readiness index 4.0 which was assessed was 2.32. In general, the 15 companies assessed are at level 2 (middle). These companies are grouped into Learning companies where companies have begun to take initiatives to implement industry 4.0. From the test results in the field also showed that the maturity model that was built in its application in the field was

able to be understood by the company so that it could be used independently to assess the readiness of 4.0.

Going forward, this research is expected to add dimension and sub-dimensions to support other types of industrial sectors to be assessed.

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