ARTICLE

Asia-Pacific Management
and Business Application
9 (3) 313-324

University of Brawijaya
Malang, Indonesia
http://apmba.ub.ac.id

Review of Industry 4.0 Strategy and Organization Readiness Level of Automotive SME's in Indonesia

Ishardita Pambudi Tama[a*]
Ceria Farela Mada Tantrika[b]
Dewi Hardiningtyas[c]
Effendi Mohamad[d]

[a,b,c]Industrial Engineering Department, Faculty of Engineering, University of Brawijaya, Malang, Indonesia; [d]Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Malaysia

Abstract

The focus of Industry 4.0 concept is to integrate production, information technology and the optimal usage of internet. It includes set of tools and applications that utilizing a smart embedded system of machines to perform a certain level of autonomous tasks in industrial system. The ideal infrastructure to perform such concept is remain a big challenge, especially for Small and Medium Enterprises (SMEs). In order to develop strategies which SMEs can get the maximum benefit from Industry 4.0, this study aims to measure their readiness level to adopt the concept. This study was conducted to fill the gap in such area of study, by adopting the "Industrie 4.0 Readiness model" by VDMA. Using survey and interview from 57 SMEs in Indonesia. Various data related with current state of knowledge and strategy implementation of Industry 4.0 were collected. The study concluded that most of the SMEs beyond the sample (56%) were still in the beginner level of adoption, 14% were even in the outsider level, and the rest of them still had no plan for the implementation. This data shows us that the implementation and adoption of Industry 4.0 in SMEs in Indonesia is still at the beginning, which need more attention from the policy and strategy maker to get to more mature level.

Keywords

Industry 4.0; readiness level; small-medium enterprises; spare part manufacturer
Received: 18 February 2021; Accepted: 10 March 2021; Published Online: 30 April 2021
DOI: 10.21776/ub.apmba.2021.009.03.9

Introduction

The trends in current technology development not only occur in the production area, but also have moved to the entire aspects of company's business. New discoveries and insights from various studies require industry to improve or modify the existing manufacturing systems. The production department which has become the center for implementing the latest technology is not sufficient to meet the increasingly diverse and fast customer demands (Hagel, J; Brown, J.S.; Kulasooriya, D.; Giffi, C.; Chen, 2015). Cross-sectional integration and the use of appropriate information technology will support the operation of business processes in meeting customer satisfaction.

*Corresponding author Email: kangdith@ub.ac.id

P-ISSN : 2252-8997
E-ISSN: 2615-2010

To face the dynamic challenges of technological, economic, social, and environmental developments, companies in the future must be able to manage the entire value-chain in an agile and responsive manner. Companies must be able to adapt quickly in line with the life cycle from innovation, production to distribution (Custom Research and Kronos Incorporated, 2016). Therefore, the industrial revolution has run and entered the latest phase, which is Industry 4.0. This term refers to recent technological advances where the internet and supporting technologies serve as a backbone to integrate physical objects, human actors, intelligent machines, production line and processes across organizational boundaries to form a new kind of intelligent, networked, and agile value chain (Gilchrist, 2016; Schumacher, Erol, & Sihn, 2016; Xu, Xu, & Li, 2018)

The concept of integrating internet and advanced technologies such as rapid prototyping and RFID into production system will bring advantages in the term of cutting bottleneck and cycle time (Wagner, Herrmann, & Thiede, 2017; Zhong, Xu, Klotz, & Newman, 2017). However, the concept also brings more complexity in the manufacturing process for both large and medium industries, let alone the small one. Particularly for small and medium-sized enterprise (SME), the financial endeavors required to acquire such new technologies can be expected to be quite challenging and have a comprehensive impact on the business model (Hamidi, Aziz, Shuhidan, Aziz, & Mokhsin, 2018; Ingaldi & Ulewicz, 2020; Rauch, Dallasega, & Unterhofer, 2019). SME's seem to only adopt a diminutive part of the Industry 4.0 concept in the production supervision process, and still show absence of real application in the field of production planning (Matt & Rauch, 2020; Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, & Barbaray, 2018). Those complex problems in implementing Industry 4.0 can be initially solved by conducting an assessment and review to determine the readiness level of industry in implementing Industry 4.0.

The development of Industry 4.0 readiness model was initially generated from a study in Germany through "IMPULSE - Industrie 4.0 Readiness" by VDMA (Schumacher et al., 2016). The model was scientifically well-rooted, and the structure and results of the study were elucidated transparently (Lichtblau et al., 2015). The model in the study was used to classify companies into three categories: newcomers, learners, and leaders. This classification is based on 6 key dimensions of Industry 4.0, i.e. strategy and organization, smart factory, smart operations, smart products, data driven services, and employees. Other models that assessed the readiness for the implementation of Industry 4.0 were also developed by PWC and Rockwell Automation (Automation, 2014) although they were lack of details, unlike the previously mentioned model developed by VDMA.

In Indonesia, Industry 4.0 does not appear to be widely implemented in both large industries and SMEs (Hadi & Murti, 2019). However, the Government of the Republic of Indonesia through the Ministry of Industry has issued a national initiative program called "Making Indonesia 4.0" (Ministry of Industry, 2018). The "Making Indonesia 4.0" initiative provides great potential to multiply workforce productivity, to increase global competitiveness and increase the share of the global export market. Indonesia will focus on five key sectors for the initial adoption of this technology, which are (i) food and beverage, (ii) textiles and clothing, (iii) automotive, (iv) chemical, and (v) electronics. These sectors are selected to be the focus after going through an evaluation of the economic impact and implementation eligibility criteria covering the size of the Gross Domestic Product, trade, potential impact on other industries, the size of investment, and the speed of market penetration.

In the supply chain of the manufacturing industry in Indonesia, large industries are not the only party that has an important role since SMEs also play an important role in producing high quality components. SMEs are one of the drivers of the country's economic development and growth (Moeuf et al., 2020; Nasution & Sarkum, 2019; Safar, Sopko, Bednar, & Poklemba, 2018; Stentoft, Adsbøll Wickstrøm, Philipsen, & Haug, 2020). Therefore, SMEs should be developed in terms of technology to optimize their operations with the integration and application of the Industry 4.0 concept. This development will direct SMEs towards Smart SME which will use technology to integrate itself from upstream to downstream, such as raw material supply, production, delivery, data collection, and inventory management to respond and reach customers more quickly (Hofmann & Rüsch, 2017) .

Component manufacturer which dominated by SMEs has been the backbone of automotive industry in various countries (Bhandubanyong & Pearce, 2017; Kotturu & Mahanty, 2017). Unfortunately, SMEs of manufacturing industry is actually still facing various challenges. The first is the underdevelopment of the domestic component industry, which results in the manufacturing process still dependent on imported components, which is strongly influenced by fluctuations in foreign exchange rates. Second, the expansion of the national manufacturing industry to the global market is confronted with environmental and energy issues that have raised concerns about the consumption of non-renewable energy. Consequently, it is an important issue regarding the readiness of the component manufacturing industry in applying the Industry 4.0 concept. In addition, there are still many component manufacturing industries that are a relatively small industry which requires assistance to understand and apply the concept (Nurcahyo & Wibowo, 2015).

There are studies related to the implementation of Industry 4.0 in the manufacturing industry, especially in developing countries. Pacchini et.al. developed a standard model based on Society of Automotive Engineers (SAE) J4000 to measure the implementation of lean manufacturing in an automotive component manufacturing company in Brazil with a modification to the principles and concepts of Industry 4.0 (Pacchini, Lucato, Facchini, & Mummolo, 2019). Technology Organizational Environment (TOE), Analytical Network Process (ANP), and VIKOR were combined to produce an assessment of the position of the food industry in Indonesia to face Industry 4.0 (Ichsan, Dachyar, & Farizal, 2019). Machado, et.al. evaluated the readiness of 7 companies to face digitization which included the causes, challenges, and support in realizing digitalization (Machado et al., 2019). A research conducted by Mohamad, et.al. produced a review of Malaysia's readiness to face Industry 4.0 challenges (MOHAMAD et al., 2018).

From these various studies, however, there is still no research related to the component manufacturing industry, especially SMEs in the context of facing Industry 4.0 (Wichmann, Eisenbart, & Gericke, 2019). Moreover, the level of automotive SME readiness in Indonesia in implementing the Industry 4.0 concept and the current conditions in carrying out its business processes are not yet discovered. In addition, strategy and organization are critical indicators because the company will be able to realize a long-term vision with the appropriate strategy and organization. Hence, in this research self-assessment and in-depth research will be carried out on the readiness of component manufacturing SMEs in Indonesia by adopting the "IMPULS - Industrie 4.0 Readiness" model in the dimension of strategy and organizations. This study aims to develop questions that support each indicator in the strategic and organizational dimensions, as well as to assess each indicator based on the current conditions. The final purpose is to attain the distribution of the level of organizational readiness and strategies of

Indonesian automotive SME to transform into a smart SME.

Methodology

To be able to help extract the required data related to the readiness of automotive SME strategies for facing Industry 4.0 , a questionnaire which adapted from the research of Lichtblau et.al (Lichtblau et al., 2015) was developed. The questionnaire consists of a description of the SME profile and questions related to strategy and organization readiness to face Industry 4.0. In the part of the questionnaire for strategy and organization readiness, the questions that lead to four indicators, i.e. degree of strategy, definition of indicators, investments, and innovation management, were compiled.

The data was collected by using purposive sampling that involves individuals that are especially knowledgeable or experienced in automotive SMEs (Palinkas et al., 2015). We conducted in-depth interview and survey for 57 SMEs' owner, who has availability and willingness to participate, and the ability to communicate experiences and opinions about their current state of business. Our respondents represent Indonesian automotive SMEs which are located in three main clusters in Indonesia, i.e. West Java Province, Central Java Province, and East Java Province.

In a next step, we transformed the automotive SMEs' owner answers into classified level according to the Industry 4.0 matrix (Lichtblau et al., 2015). From the average of all respondents for each indicator, the highest to lowest indicator values can be obtained, and then the level of strategic and organizational readiness will be evaluated in implementing Industry 4.0 for Indonesian automotive SME.

Results and Discussion

The data collected from 57 experts who were the owners of automotive SMEs was then analysed to obtain an overview of the business strategy to date. Some of these SMEs have joined business groups assisted by the large automotive industry either as business partners or not. This assistance aims to ensure that even though the spare parts production process is carried out at the micro level, it still produces quality products that meet the requirements of the automotive industry being supplied. The reason is that the precision of the spare parts is a critical factor for the quality of the spare parts themselves, and the precision results from a guaranteed process.

Industry 4.0 not only improves the currently available products and processes through the use of digital technology, but also provides opportunities to develop new business models for companies. For this reason, the implementation is strongly influenced by the strategy and organization in the company. Accordingly, related indicators are employed to assess this, including (a) the status of the Industry 4.0 implementation strategy; (b) the strategy operationalization through indicators; (c) the investments made in relation to Industry 4.0; and (d) the use of innovation management and technology. The owner's basic knowledge of Industry 4.0 was extracted from the answers depicted in Figure 1. The figure shows that 93% of SMEs have heard of Industry 4.0, but with different levels of understanding, i.e. 37% of them still do not understand, 46% already understand, and only 9% are already implementing it.

Figure 1. Recent Knowledge Related with Industry 4.0

In line with the understanding of Industry 4.0, in Figure 2, the level of implementation of Industry 4.0 strategy was still not satisfactory because only 37% of them started to have the strategy 5% of which have already been implemented. Meanwhile, the remaining 47% were still limited to initiatives and the other 16% did not have strategies altogether to make the transition to companies with Industry 4.0.

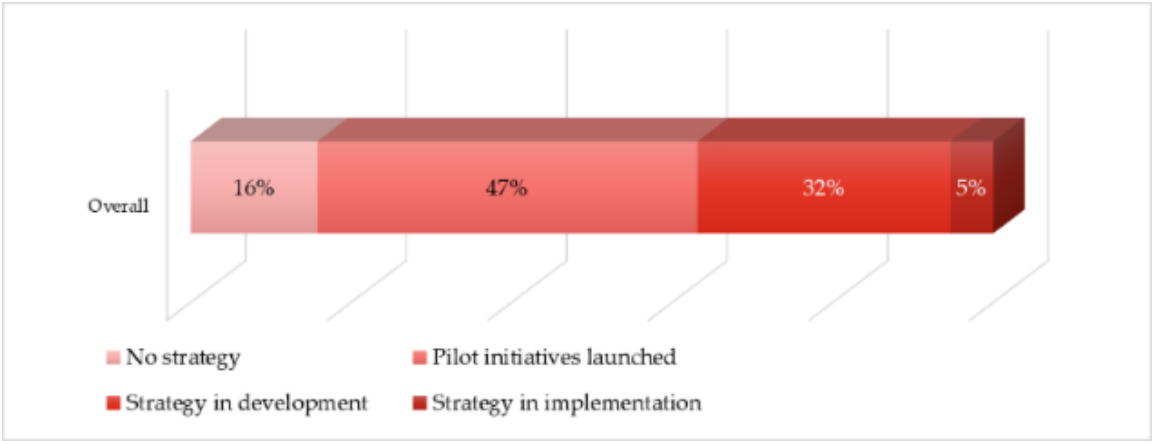


Figure 2. Implementation Status of Industry 4.0 Strategy

Although 37% already had the strategies, 89 % of them were not specific and the indicator system to measure the status of Industry 4.0 implementation was not clearly determined yet. Only 11% felt that they had a sufficiently targeted indicator system as shown in Figure 3. This shows that, at the micro level, the understanding of Industry 4.0 is still limited to a definitive general understanding. Meanwhile, more detailed understanding such as on operationalizing indicators that can help measure the success of implementation has not been realized. This may occur due to the fact that apart from limited access to information on this issue, it is also due to a lack of ongoing mentoring and training as well as support in implementing Industry 4.0. Business actors at both the micro and macro levels, government and society need synergy to jointly support the realization of the Smart SME pilot project in Indonesia.

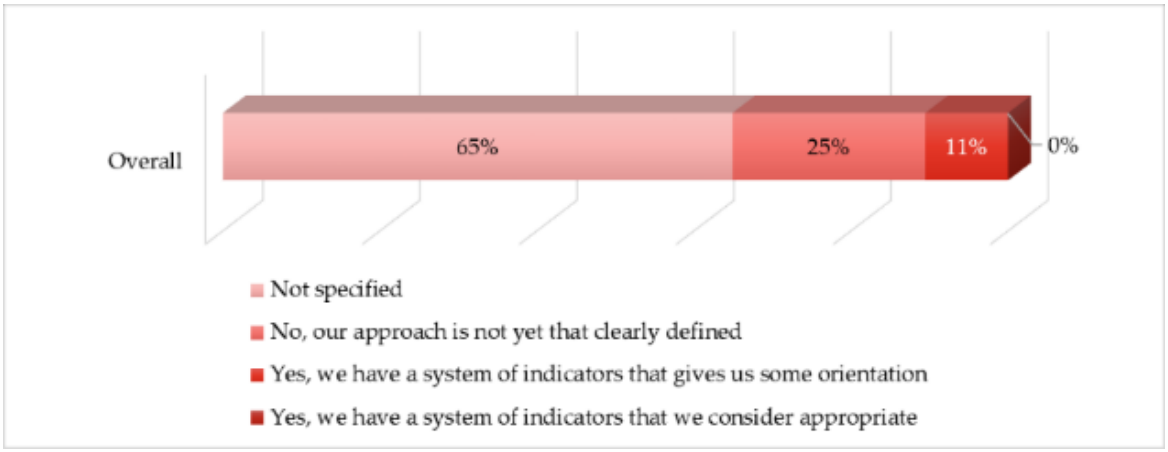
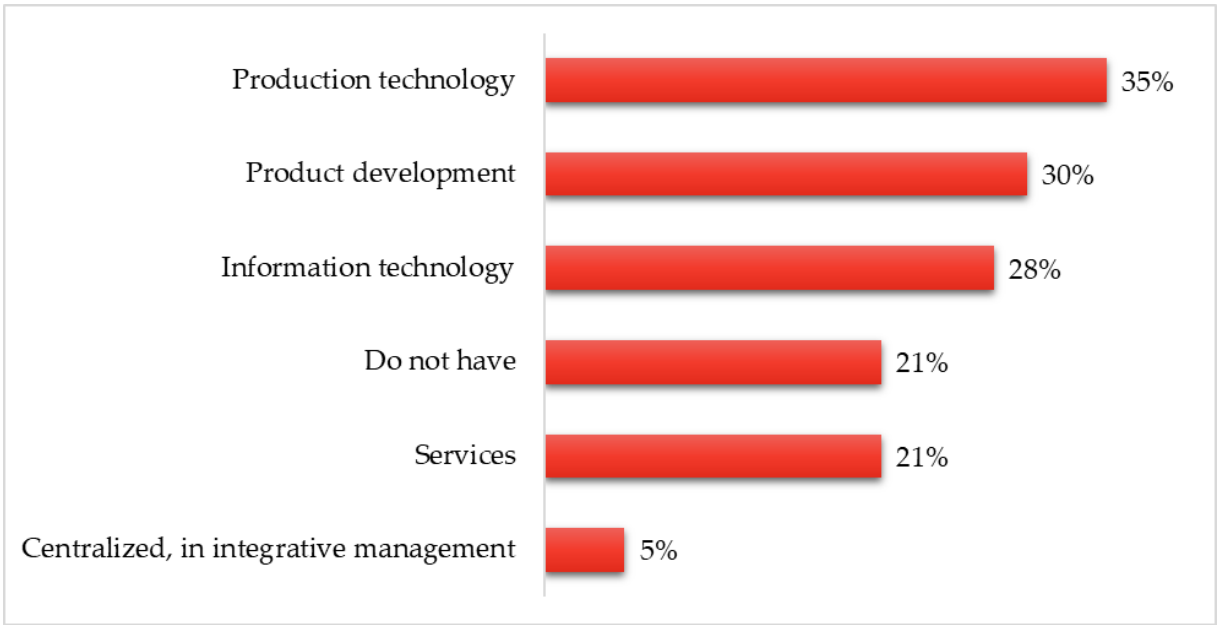


Figure 3. Use of a System of Indicators

New technological innovations are required to digitize processes and products by optimizing the functions of information technology as the backbone of implementing Industry 4.0. Even though it is gradual, the infrastructure series needs to be planned carefully so that continuous improvement occurs in order to achieve Smart SME. Based on Figure 4a, it is identified that 21% have not used digital technology in all of their departments. This group is still classified as conventional with a business focus on only producing limited quantities of products according to demand. Meanwhile, some others have used information technology infrastructure to support business processes both in one department and in several departments at once. The departments that utilized the implementation of digitization the most were in the production department, followed by the product development, information systems, and services. Meanwhile, the least implementation was in integrated management. The technology used, however, was mostly still limited to mobile end devices, as shown in Figure 4b. Other technologies that have not been utilized are possible because they require a relatively high investment value.



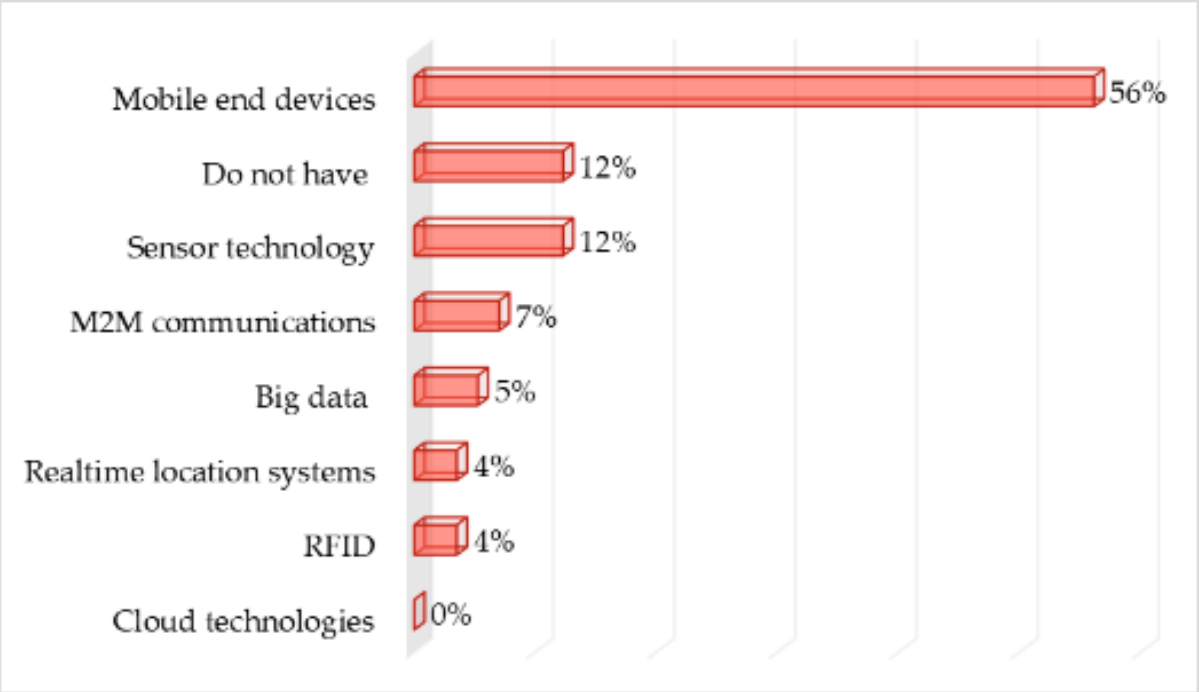


Figure 4. (a) Area of Implemented Technology
(b) Technology used to Support the Business Process

In general, automotive SMEs surveyed in this study were still investing in the implementation of Industry 4.0 in a relatively small amount compared to their annual opinion. This can be observed from the current technology that was not sufficient to increase the level of Industry 4.0 implementation. However, the respondents were optimistic about investing in the next two and five years, especially in the production, buyers and sales sectors. These three are the most attractive sectors to invest in technology in the future.

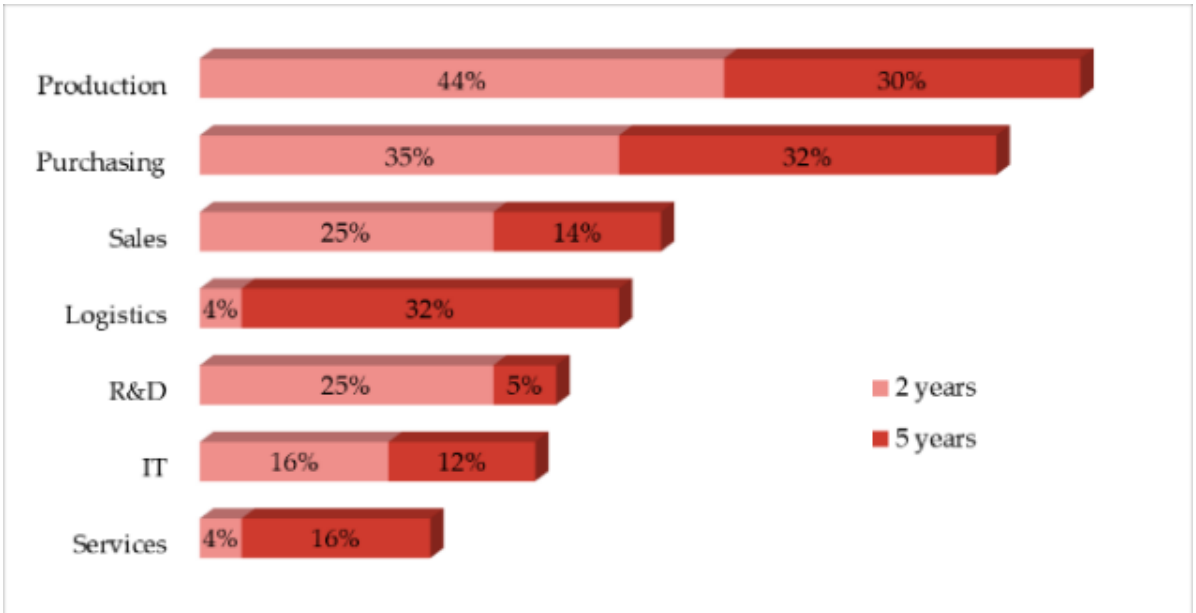


Figure 5. Planned Investments in Industry 4.0

In order to increase understanding of the level of automotive SME strategy and organizational readiness in implementing Industry 4.0, the results of questionnaire

answers and interviews were converted and tabulated into numerical values indicating their level. Each value was then calculated as an average for each indicator in the strategic and organizational dimensions, which include the degree of strategy, definition of indicators, investments, and innovation management.

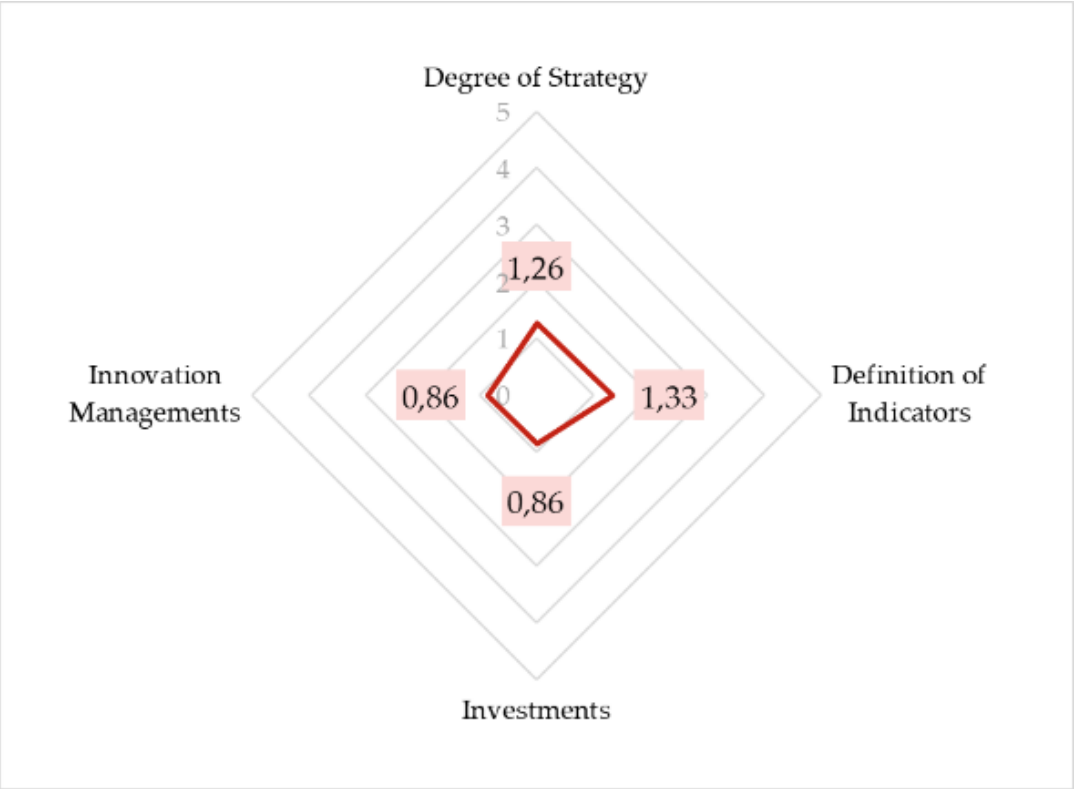


Figure 6. Result of Indicators in Strategy and Organization dimension

A radar chart is used to depict the overall result at-a-glance as displayed in Figure 6. In this figure, there are five levels ranging from 1 to 5 which indicate the level of SME readiness, i.e. outsider, beginner, intermediate, experienced, expert, and top performers. If all the levels are identified, the five levels are grouped into 3 groups, which are newcomers (outsider and beginner), learners (intermediate), and leaders (experienced, expert, top performer) even though currently it is still focused on the dimensions of strategy and organization. Figure 7 shows that the highest level was achieved by the indicator "definition of indicators" and was followed by "degree of strategy", while "innovation management" and "investments" were at the same value. However, the highest-level value has not yet reached level 2 (intermediate) because the value of 1.33 is still classified as a beginner.

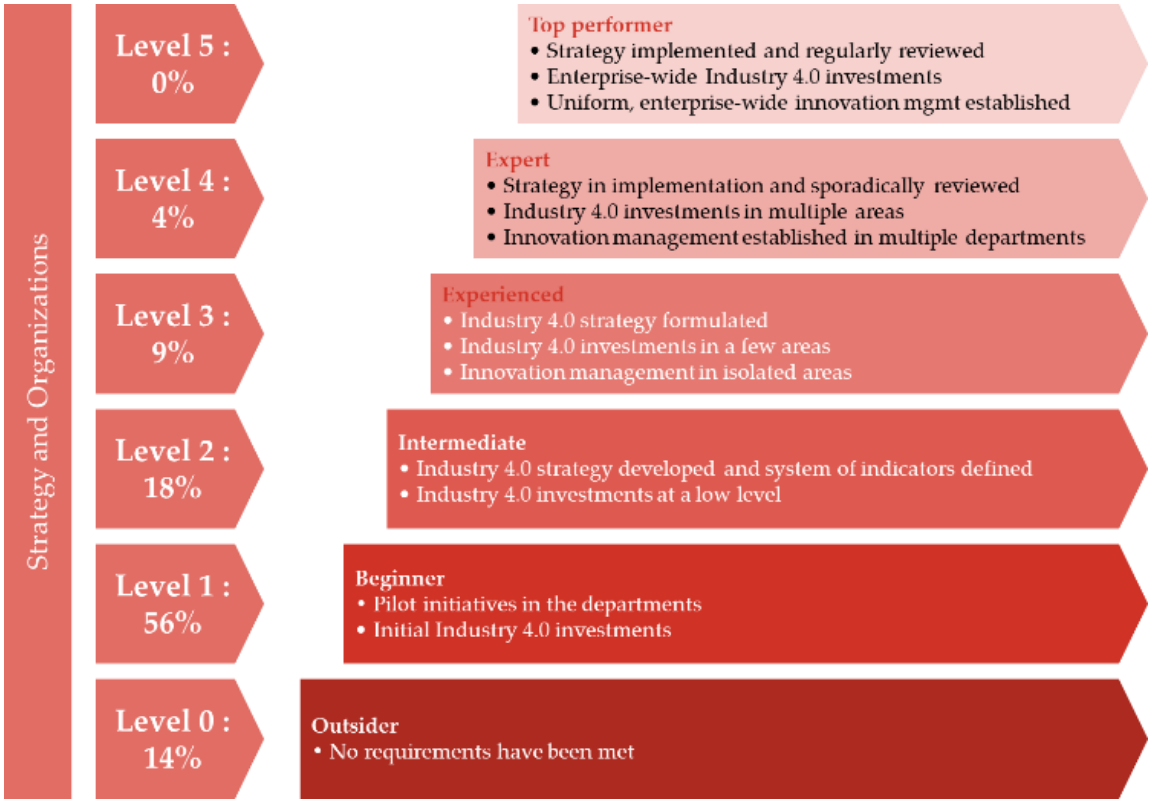


Figure 7. Readiness level in the Dimension of Strategy and Organization (Adapted from Litchblau et.al. (Lichtblau, et al., 2015))

These results can be employed as an evaluation for the automotive SMEs themselves, the government and other interested parties that for the micro industry in Indonesia, which are engaged in component manufacturing, in general, they have not carried out any significant activities to implement Industry 4.0. Figure 8 shows the percentage of Indonesian automotive SMEs at each strategic readiness level. 14% of them were at Level 0 which is considered an outsider because they do not have the initiative, let alone the investment. The largest composition was at Level 1 by 56% or beginners who already have initiatives but have not implemented and invested on Industry 4.0. Meanwhile, there were 18% at level 2 (intermediate), 9% were at level 3 (experienced), and 4% were at level 4 (expert), but none has reached level 5 (top performer).

Unquestionably, the concept of Industry 4.0 offered a plethora of advantages (Petrillo, Felice, Cioffi, & Zomparelli, 2018) especially by shaping how manufacturing industries doing their business in the future. However, manufacturing industries in developed countries is still struggling to grab those advantages to the fullest (Castelo-Branco, Cruz-Jesus, & Oliveira, 2019), nonetheless their counterpart in developing countries. This study is certainly supporting that statement. Majority of industries in developing countries, like in Indonesia, are in SME level and while they might have been introduced with the concept of Industry 4.0, they are still struggling with production and marketing issues on a day-to-day basis, let alone implementing new concept of manufacturing.

Conclusion

This research was conducted with the aim of understanding each indicator in the strategic and organizational dimensions, and the level of strategic and organizational readiness of automotive SMEs in Indonesia in order to implement Industry 4.0. In the adapted model, there are 6 dimensions, but this study focused only on the dimensions of strategy and organization. In order to produce a more

detailed picture, a questionnaire was developed as a tool to extract data and information from 57 automotive SMEs in three main industrial cluster in Indonesia. In addition, in-depth survey and interview was conducted and the data were tabulated to provide a state-of-development overview.

According to the results of quantitative and qualitative studies conducted, the level of strategic readiness and organization of automotive SMEs in Indonesia can be identified. Most of these automotive SMEs are still at level 1 or beginners and still need guidance and assistance to deal with the obstacles in developing strategies and making innovations and investments.

Further research is required to identify the readiness level of component manufacturing SMEs in Indonesia in other dimensions. The same approach can be employed because it is suitable enough to obtain the necessary information.

Acknowledgements

Author wish to acknowledge the Ministry of Education and Culture, Indonesia and Faculty of Engineering, Universitas Brawijaya for sponsoring this publication under Assistant Professor Research Grant.

Notes on Contributors

Ishardita Pambudi Tama is a senior lecturer at the Industrial Engineering Department, Universitas Brawijaya. His research interests concern with developing dynamics modeling related to the readiness implementation of Industry 4.0 from small medium enterprises to global industry.

Ceria Farela Mada Tantrika is a senior lecturer at the Industrial Engineering Department, Universitas Brawijaya. Her research interests concern with production planning and scheduling.

Dewi Hardiningtyas is a lecturer at the Industrial Engineering Department, Universitas Brawijaya. Her research interests concern with human-system interaction and also safety engineering implementation in any production activities.

Effendi Mohamad is a senior lecturer at the Faculty of Manufacturing Engineering, UTeM. His research work concerns with manufacturing systems, lean manufacturing, technology management, and cleaner production.

References

Automation, R. (2014). *The Connected Enterprise Maturity Model*.

Bhandubanyong, P., & Pearce, J. T. H. (2017). *Appraisal of SME Casting Industry in Thailand*. *INTERNATIONAL SCIENTIFIC JOURNAL OF ENGINEERING AND TECHNOLOGY (ISJET)* (Vol. 1). Retrieved from https://ph02.tci-thaijo.org/index.php/isjet/article/view/175753

Castelo-Branco, I., Cruz-Jesus, F., & Oliveira, T. (2019). Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union. *Computers in Industry*, *107*, 22–32. https://doi.org/10.1016/j.compind.2019.01.007

Custom Research and Kronos Incorporated. (2016). The Future of Manufacturing: 2020 and Beyond. *Industry Week*, 12. Retrieved from https://www.nist.gov/sites/default/files/documents/2016/11/16/iw_kronos_research_report_2016.pdf

Gilchrist, A. (2016). *Industry 4.0. 2030 Agenda and the Sustainable Development Goals (SDGs)*. Berkeley, CA: Apress. https://doi.org/10.1007/978-1-4842-2047-4

Hadi, S., & Murti, H. W. (2019). KAJIAN INDUSTRI 4.0 UNTUK PENERAPANNYA DI INDONESIA. *Jurnal Manajemen Industri Dan Logistik*. https://doi.org/10.30988/jmil.v3i1.59

Hagel, J; Brown, J.S.; Kulasooriya, D.;

Giffi, C.; Chen, M. (2015). The Future of Manufacturing - Making things in a changing world. *Deloitte University Press*, 1–50. https://doi.org/10.1049/tpe.1971.0034

Hamidi, S. R., Aziz, A. A., Shuhidan, S. M., Aziz, A. A., & Mokhsin, M. (2018). SMEs maturity model assessment of IR4.0 digital transformation. In *Advances in Intelligent Systems and Computing*. https://doi.org/10.1007/978-981-10-8612-0_75

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, *89*, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Ichsan, M., Dachyar, M., & Farizal. (2019). Readiness for Implementing Industry 4.0 in Food and Beverage Manufacturer in Indonesia. In *IOP Conference Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/598/1/012129

Ingaldi, M., & Ulewicz, R. (2020). Problems with the implementation of industry 4.0 in enterprises from the SME sector. *Sustainability (Switzerland)*, *12*(1), 217. https://doi.org/10.3390/SU12010217

Kotturu, C. M. V. V., & Mahanty, B. (2017). Determinants of SME integration into global value chains: Evidence from Indian automotive component manufacturing industry. *Journal of Advances in Management Research*, *14*(3), 313–331. https://doi.org/10.1108/JAMR-02-2017-0013

Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., … Schröter, M. (2015). *INDUSTRIE 4.0 READINESS*.

Machado, C. G., Winroth, M., Carlsson, D., Almström, P., Centerholt, V., & Hallin, M. (2019). Industry 4.0 readiness in manufacturing companies: Challenges and enablers towards increased digitalization. In *Procedia CIRP* (Vol. 81, pp. 1113–1118). Elsevier B.V. https://doi.org/10.1016/j.procir.2019.03.262

Matt, D. T., & Rauch, E. (2020). SME 4.0: The role of small-and medium-sized enterprises in the digital transformation. In *Industry 4.0 for SMEs: Challenges, Opportunities and Requirements* (pp. 3–36). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-25425-4_1

Ministry of Industry. (2018). Indonesia's Fourth Industrial Revolution Making Indonesia - Making Indonesia 4.0. *Kementerian Perindustrian*.

Moeuf, A., Lamouri, S., Pellerin, R., Tamayo-Giraldo, S., Tobon-Valencia, E., & Eburdy, R. (2020). Identification of critical success factors, risks and opportunities of Industry 4.0 in SMEs. *International Journal of Production Research*, *58*(5), 1384–1400. https://doi.org/10.1080/00207543.2019.1636323

Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The industrial management of SMEs in the era of Industry 4.0. *International Journal of Production Research*, *56*(3), 1118–1136. https://doi.org/10.1080/00207543.2017.1372647

MOHAMAD, E., SUKARMA, L., MOHAMAD, N. A., SALLEH, M. R., RAHMAN, M. A. A., RAHMAN, A. A. A., & SULAIMAN, M. A. (2018). Review on Implementation of Industry 4.0 Globally and Preparing Malaysia for Fourth Industrial Revolution. *The Proceedings of Design & Systems Conference*. https://doi.org/10.1299/jsmedsd.2018.28.2203

Nasution, A. P., & Sarkum, S. (2019). Strategy for Developing the Local Foundation for Small Business Enterprise in Indonesia: A Review of the Industrial Revolution 4.0. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3409383

Nurcahyo, R., & Wibowo, A. D. (2015). Manufacturing capability, manufacturing strategy and performance of Indonesia automotive component manufacturer. In *Procedia CIRP* (Vol. 26, pp. 653–657). Elsevier B.V. https://doi.org/10.1016/j.procir.2014.07.046

Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. *Computers in Industry*, *113*, 103125. https://doi.org/10.1016/j.compind.2019.103125

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Petrillo, A., Felice, F. De, Cioffi, R., & Zomparelli, F. (2018). Fourth Industrial Revolution: Current Practices, Challenges, and Opportunities. *Digital Transformation in Smart Manufacturing*, 1–20. https://doi.org/10.5772/intechopen.72304

Rauch, E., Dallasega, P., & Unterhofer, M. (2019). Requirements and Barriers for Introducing Smart Manufacturing in Small and Medium-Sized Enterprises. *IEEE Engineering Management Review*, *47*(3), 87–94. https://doi.org/10.1109/EMR.2019.2931564

Safar, L., Sopko, J., Bednar, S., & Poklemba, R. (2018). Concept of SME Business Model for Industry 4.0 Environment. *TEM Journal*, *7*(3), 626–637. https://doi.org/10.18421/TEM73-20

Schumacher, A., Erol, S., & Sihn, W. (2016). A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. In *Procedia CIRP* (Vol. 52, pp. 161–166). Elsevier B.V. https://doi.org/10.1016/j.procir.2016.07.040

Stentoft, J., Adsbøll Wickstrøm, K., Philipsen, K., & Haug, A. (2020). Drivers and barriers for Industry 4.0 readiness and practice: empirical evidence from small and medium-sized manufacturers. *Production Planning and Control*. https://doi.org/10.1080/09537287.2020.1768318

Wagner, T., Herrmann, C., & Thiede, S. (2017). Industry 4.0 Impacts on Lean Production Systems. In *Procedia CIRP* (Vol. 63, pp. 125–131). Elsevier B.V. https://doi.org/10.1016/j.procir.2017.02.041

Wichmann, R. L., Eisenbart, B., & Gericke, K. (2019). The Direction of Industry: A Literature Review on Industry 4.0. *Proceedings of the Design Society: International Conference on Engineering Design*. https://doi.org/10.1017/dsi.2019.219

Xu, L. Da, Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent Manufacturing in the Context of Industry 4.0: A Review. *Engineering*, *3*(5), 616–630. https://doi.org/10.1016/J.ENG.2017.05.015