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The mark of industry 4.0: how managers respond to key revolutionary changes

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Abstract

Purpose – The purpose of this study is to provide a framework of managerial responses to the Industry 4.0 phenomenon, which has impacted the productivity of Indonesian manufacturing companies while revolutionizing global industries.

Design/methodology/approach – The study employs qualitative research using the Grounded Theory Method since research in this area is still in its preliminary stages. The study elicits insights from 12 operation managers through a semi-structured interview and a focus group discussion. Using content analysis, the study formulates relationships among Industry 4.0 initiatives, its driving factors and challenges as well as critical success factors and the expected benefits.

Findings – The findings reveal that Indonesian manufacturers have engaged in Industry 4.0 initiatives: cyber-physical systems, the internet of things, Big Data and cloud computing. These initiatives require managers to adopt best practices, appoint champions as change agents, conduct training and even tailor the job qualifications of their subordinates to suit the current technology.

Research limitations/implications – The qualitative method allows an in-depth investigation that is synthesized into a conceptual framework, but this framework still needs to be empirically tested. The study is currently based on informants from large manufacturing companies. Future studies could scale up the research and validate the findings.

Practical implications – This exploratory framework could guide managers in their strategic and operational decisions while embracing the Industry 4.0 transformation inside the organization.

Originality/value – Prior studies examining the adoption of Industry 4.0 principles by Indonesian manufacturing companies are rare. Furthermore, conceptual studies dominate the existing literature related to the Industry 4.0 concept. This study attempts to fill the gap and provides a framework that is based on grounded empirical data of manufacturing companies in Indonesia, a newly industrialized economy.

Keywords Industry 4.0, Indonesian manufacturing firms, Grounded theory method

Paper type Research paper

1. Introduction

The term "Industry 4.0" was first introduced at the 2011 Hannover Fair in Germany and sparked considerable attention from scholars, practitioners and government representatives (Sung, 2018; Erro-Garcés, 2019). The concept, initially a high-technology strategy promoted by the German government, refers to the transformation of industries towards fully integrated, optimized and digitized manufacturing systems (Kagermann *et al.*, 2013). Vaidya *et al.* (2018) described Industry 4.0 as "a new level of organization and control over the entire value chain of the life cycle of products" (p. 233).

Some scholars argue that the Industry 4.0 strategy should not be confused with the Fourth Industrial Revolution, which is broader, more expansive and impacts not only industries but also societies, human identity and economies (Schwab, 2016; Sung, 2018). Indeed, the Fourth Industrial Revolution—marked by the technological advancement in "physical, digital and biological worlds"—significantly triggered the Industry 4.0 phenomenon in industries

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(Schwab, 2016). However, the Industry 4.0 concept applies to automated and digitized processes, systems and machines within industries. According to Weyer *et al.* (2015), Industry 4.0 embraces three characteristics: smart products, smart machines and augmented operators. As Sung (2018) described in his studies, a "machine will operate independently or will coordinate with humans to produce customer-oriented manufacturing, that constantly works to maintain itself" (p. 41).

Even though scholars have not reached a solid consensus regarding the definition of Industry 4.0 (Schlund and Baaij, 2018), they generally agree on several major forces that drive this phenomenon: the internet of things (IoTs), cloud computing, cyber-physical systems and Big Data (Kagermann *et al.*, 2013; Magruk, 2016; Vaidya *et al.*, 2018; Cordeiro *et al.*, 2019; Klingenberg *et al.*, 2019). The vibration of the Industry 4.0 phenomenon becomes universal as industries connect globally. Indonesia, as one of the fastest-growing economies in the Asian region, has responded to these revolutionary changes by officially undertaking initiatives to improve industrial productivities and growth (as stated on the official website of the Indonesian Ministry of Industry). Aside from strengthening vocational education, the ministry also requested Indonesian industries to use digital technology, including Big Data, autonomous robots, cybersecurity, cloud computing and augmented reality, to increase efficiency and reduce costs by around 12–15%. Three manufacturing industries have embraced the changes caused by Industry 4.0: the cement, petrochemical and food and beverage industries. These changes, among others, are implementing smart sensors in their production lines and using robotic systems or IoT-based infrastructure in their manufacturing operations.

Despite indications of the adoption of Industry 4.0 in manufacturing companies in Indonesia, research examining its widespread changes is scarce. Indonesia has been positioned as one of the "newly industrialized economies in global value chains" (Boddin, 2016, p. 5). A newly industrialized country (NIC) differs from a developing country in that its economy grows remarkably and often at an even higher rate than that of a developed country.

It is pertinent to investigate the extent to which Indonesian managers comprehend the situation and make strategic or tactical decisions about Industry 4.0 practices. The findings could be exemplars of Industry 4.0 adoption for other NICs, such as Brazil, China, India, Mexico and Turkey. Furthermore, existing literature related to the Industry 4.0 phenomenon is dominated by conceptual studies (e.g. Magruk, 2016; Zhang *et al.*, 2016; Sung, 2018; Vaidya *et al.*, 2018) especially in the Engineering literature (Muhuri *et al.*, 2019), and studies that provide empirical evidence are limited (e.g. Lin *et al.*, 2018). Studies that synthesize prior research do not introduce new empirical findings. Therefore, one research question will guide the study:

RQ1. How do operations managers at manufacturing companies in Indonesia respond to Industry 4.0 initiatives?

Drawing from the empirical findings, this study aims to provide a theoretical framework that could assist managers in responding to the Industry 4.0 revolution. The scope of the work performed by operations managers would be most affected by Industry 4.0 because such managers deal with production machines, systems and technologies. Moreover, these managers serve as leaders at their plant, and their competencies contribute to their company's performance (Almatrooshi *et al.*, 2016).

This study contributes to the literature by revealing managers' interpretations and actions associated with the Industry 4.0 revolution in an NIC. Since this industrial phenomenon is current and dynamic, an exploratory study using Grounded Theory Method (GTM) is deemed suitable. In return, this study will provide a deeper understanding of this revolutionary change.

The remaining part of this paper is structured as follows. The next section synthesizes prior research regarding Industry 4.0. Section 3 describes the methodology of the current

study, followed by the details of the findings. Section 13 discusses the theoretical and managerial implications of these results. Finally, the last section presents the conclusions and limitations of the study, which provide avenues for future research.

2. Literature review

2.1 The evolution of industry 4.0

This industrial revolution marks the fourth significant change in the world, after the discovery and use of steam power in the eighteenth century, the subsequent invention and use of electricity to manufacture mass products in the 19th century and the development and use of computer technology in the twentieth century (Zhang *et al.*, 2016; Muhuri *et al.*, 2019; Rejikumar *et al.*, 2019). Industries have attempted the advanced technologies characterizing Industry 4.0 since the German government named them as their strategies to increase global competitiveness in 2013. Beginning with the development of sophisticated technology and its use in the broader community, this phenomenon began to emerge in manufacturers around the world (Magruk, 2016; Cordeiro *et al.*, 2019). In Germany, traditional plants were transformed into smart factories to produce customized products (Kagermann *et al.*, 2013; Weyer *et al.*, 2015; Zhang *et al.*, 2016).

Because of the development of advanced technology and the Internet, companies must invest in information and computer technology (ICT) while pursuing Industry 4.0 initiatives. The impacts of the Industry 4.0 revolution are, among others (Magruk, 2016; Sung, 2018; Vaidya *et al.*, 2018):

(1) A need for new expertise in data analytics and corporate digitization;

(2) Data security as a significant consideration;

(3) Horizontal networks with critical suppliers, customers and partners in the value chain, as well as vertical networks from product development, procurement, manufacturing and distribution;

(4) A decline in human resource requirements with current expertise.

The expected benefits are numerous and include increased process and product flexibility (Magruk, 2016; Birkel *et al.*, 2019; Dalenogare *et al.*, 2018), improved decision-making capabilities aided by big-data analytics (Dalenagore *et al.*, 2018), increased company productivity (Dalenogare *et al.*, 2018; Rejikumar *et al.*, 2019) and competitiveness (Müller *et al.*, 2018). However, a large-scale study by Dalenogare *et al.* (2018), who examined the use of various technologies in manufacturing companies in Brazil, showed that not all technological investments had a positive impact on companies' operational performance. There are still ample opportunities to validate these findings within the contexts of other developing countries.

In reality, various obstacles can counteract the potential benefits that companies might attain when adopting Industry 4.0 programs. These obstacles include difficulties in synergizing between organizational structures/systems and their production teams (Müller *et al.*, 2018; Culot *et al.*, 2020), prompting stakeholders to make necessary transformations (Sung, 2018) and the lack of competent experts and human resources (Zhang *et al.*, 2016; Sung, 2018). In their study, Birkel *et al.* (2019) have provided a comprehensive framework of risks associated with the implementation of Industry 4.0 initiatives. The framework captured the economic, ecological, social, technical, information technology-related, legal and political risks. The researchers also anticipated job losses and employee resistance as potential problems related to the adoption of Industry 4.0 practices.

Specific for developing countries, Dalenogare *et al.* (2018) added several essential aspects—namely, the cultural, economic and political conditions of a nation, especially in

emerging countries. Despite these many obstacles, Ghobakhloo (2018) argued that pursuing Industry 4.0 initiatives is no longer an option, but a necessity.

2.2 Empirical research regarding the industry 4.0 phenomenon

Many studies have attempted to examine Industry 4.0 since the terminology was coined in 2011 and its implementation spread across the globe. These analyses employed various approaches, including both conceptual studies and empirical research. Until recently, explorative and theoretical studies were dominant. Rejikumar *et al.* (2019) examined 85 articles on Industry 4.0 (between 2013 and 2017) and found that only 18% of Industry 4.0 research utilized a case study approach, and just 4% were empirical studies. This finding provides an excellent chance to develop more empirical research on Industry 4.0 initiatives implemented by companies.

In applying these initiatives, Rejikumar and colleagues suggested that companies pinpoint aspects of this concept that ensure the programs' effectiveness in terms of process integration, employee training and organizational agility. Along the same line, scholars argued that companies need to assess not only their willingness to pursue an Industry 4.0 transformation but also their readiness to endure the journey. The assessment comprises the all-encompassing features of an organization: more specifically, organizational strategy, products and services, supply chain and business process (Akdil *et al.*, 2018; Sony and Naik, 2019). Furthermore, one of the empirical studies conducted by Lin *et al.* (2018), who examined 165 respondents from 37 automotive manufacturing companies in China, found that all aspects of technology, organization and the environment triggered the use of advanced production technologies in the era of Industry 4.0.

A few studies further documented and described the implementation of Industry 4.0 initiatives in manufacturing companies in various countries, including the Czech Republic (Basl, 2017), China (Zhang *et al.*, 2016), Germany (e.g. Weyer *et al.*, 2015; Schneider, 2018; Veile *et al.*, 2019), Korea (Sung, 2018) and New Zealand (Hamzeh *et al.*, 2018). These studies highlighted the significance of human resources and culture in pursuing Industry 4.0 transformation.

Moreover, even though these studies examined countries with different levels of wealth, they coherently argued that the maturity of ICT and strength of funding were also pertinent factors in the effectiveness of the Industry 4.0 initiatives.

3. Methodology

This study aims to investigate managers' strategic and operational actions while transforming their companies to embrace Industry 4.0 ideals. In essence, this study provides a framework, which could inspire the managers' counterparts in responding to the Industry 4.0 phenomenon. As the Industry 4.0 initiative initially targeted the improvement of manufacturing industries before it became a massive, global revolution, this study also investigates its potential contribution to the productivity of manufacturing industries in Indonesia.

Due to the preliminary nature of research related to Industry 4.0, this study employs a qualitative study using GTM for its exploration. GTM (Glasser and Strauss, 1967) was initially developed by two sociologists: Barney Glaser and Anselm Strauss. GTM develops theories that emerge from or are "grounded" in the data, as opposed to depending upon variables from pre-existing theories (Corbin and Strauss, 1990; Charmaz, 1996). Nevertheless, the use of GTM does not necessarily connote ignorance of literature or a systematic procedure (Suddaby, 2006); consequently, this study contains a rigorously designed methodology, which is described in detail below.

3.1 The research context: Indonesia

Indonesia is an emerging country located in Southeast Asia. It ranks fourth in world population, and before the COVID-19 pandemic hit this and other economies globally, Indonesia was one of the largest economies in Southeast Asia. Additionally, it is the 16th largest economy by nominal GDP, the 7th by PPP GDP (World Bank, 2020) and steadily grew around 5%–5.5% annually (Felipe *et al.*, 2019).

Studying Industry 4.0 in Indonesia is pertinent since it is classified as a newly industrialized country (Boddin, 2016). Its economy is expanding due to the growth of its service and manufacturing sectors, and those manufacturing sectors account for 20% of its GDP. Large firms, which are only around 1% of the total manufacturers, contribute approximately 80% of the manufacturing value added in Indonesia (Felipe *et al.*, 2019).

Furthermore, the Asian Development Bank documented that Indonesian high-technology manufactures, such as pharmaceutical companies, are instrumental in a significant share of the value added (currently 40%). The share from high-technology manufacturers has grown four times within the last decade (Felipe *et al.*, 2019).

Yet, the World Bank and the Asian Development Bank classified Indonesia industries as less-advanced and less-modernized compared to those of Asian countries. In the long run, this could hinder Indonesia from becoming truly industrialized and competitive. The Industry 4.0 industrial revolution offers opportunities as well as challenges for Indonesian manufacturing industries. A study of the response of manufacturing companies in Indonesia in the era of Industry 4.0 can significantly contribute to the growth of emerging economies globally.

3.2 Unit of analysis and informants

The unit of analysis of this study was operation managers in the manufacturing industry in Indonesia. These managers served as the informants of the study and were asked to reveal their specific responses or actions in resolving issues or challenges attributable to Industry 4.0 initiatives.

Accessing informants was challenging since there is neither a directory of the Indonesian manufacturing industry nor a list of Indonesian operation managers; therefore, this study used convenience procedure to contact potential informants. Nevertheless, several criteria were employed to screen the appropriate persons:

(1) The informant should be an operation manager or a person who is in charge of company operations;

(2) The informant should work in the manufacturing industry;

(3) The informant should work for at least one year in the current company.

Scholars have acknowledged the time and budget limitations of research projects (Strauss and Corbin, 1998; Timonen *et al.*, 2018). Hence, the current study settled on 12 informants. These informants who would be interviewed were selected using the criteria above. Nine informants were operation managers, two were senior staff members who were in charge of operational functions at the company and one was a marketing and operation director of a manufacturing company. All of them were in charge of company operations and had joined their current company for more than one year before their involvement in the study.

3.3 Data collection procedure

The study obtained data through in-depth interviews and a focus group discussion (FGD). In the beginning, the researchers contacted each informant to set a date for an interview. We also asked if the informants had heard of the concept of Industry 4.0 and if the company that they work for had implemented any Industry 4.0 initiatives.

All informants were familiar with the Industry 4.0 phenomenon, but out of twelve, only seven had already implemented the programs. For those who engaged in Industry 4.0 projects, we set a time for an in-depth interview that best suited the managers' hectic schedules. For the last five individuals who knew Industry 4.0 but were merely at the beginning of its implementation, we set up a FGD to have a more fruitful conversation.

The process of data collection for the GTM should ideally stop when a researcher attains a theoretical saturation (Charmaz, 2006; Strauss and Corbin, 1998); therefore, we did not determine a specific number of samples at the beginning. Thomson (2011) recommended that researchers should "allow data to dictate the sample size" (p. 49), which usually "occurs between 10 and 30 interviews" (p. 50). As the interview progressed, we contacted more informants and set meetings with them. For those who were at the beginning stages of Industry 4.0 implementation, we arranged a group discussion for them to avoid having only brief conversations.

All data collection was performed face-to-face. The FGD lasted for 60 min, while the interviews ranged between 41 and 70 min. The researchers conducted all means of data collection in Bahasa Indonesia (the native Indonesian language) to warrant smooth conversation and to stay clear of any misperceptions. The researchers recorded both the FGD and the interviews with the informants' consent. To enrich the findings and validate the FGD and interview, we also utilized observation notes from a plant visit.

3.4 Data analysis

GTM recognizes data collection and analysis as simultaneous processes (Corbin and Strauss, 1990). This study examined data from each interview at the same time as the data collection period, which enabled the researchers to improve their probing of each subsequent informant to create richer conversations during the interview.

A professional transcriber performed the data transcription. Along with the data collection process, the researchers conducted a content analysis of each transcript and compared one informant's response with the others' to gain insights and to elicit deeper meaning. Stark and Trinidad (2007) suggested that a researcher should pay more attention to the association among the informants' experiences rather than their subjective opinions. This study coded the informants' responses, found similarities and differences and attempted to make relations for further framework proposition.

4. Findings

This study gathered data through semi-structured interviews and FGDs with 12 operations managers from 11 different companies, which allowed the researchers to elaborate more questions and have insightful conversations. Table 1 details the profile of each informant.

All informants met the criteria of the study and came from various industries—by chance, the majority worked at a large manufacturing company. The ownership types of their companies varied from a family business, a state-owned company, a public limited company, to a multinational enterprise.

We coded the findings of the seven interviewed informants apart from those of the other informants. Table 2 details the responses of the former, while Table 3 presents the results of the latter. Through the interviews, this study found that all informants had heard Industry 4.0 jargon. Three informants had heard it since 2016, while the other two informants heard just recently and became more aware when the researchers contacted them. However, their perceptions regarding the Industry 4.0 phenomenon varied.

The first informant (Informant A) described Industry 4.0 as a phenomenon wherein "machines communicate with [the] server." Informants B and D translated the phenomenon

ID	Current title	Industry	Ownership type	Company size	Methods of collecting data
A	Marketing and operations director (company 1)	3448 – prefabricated metal buildings and components	Family-owned	Large	Interview and plant visit
B	Production manager (company 2, plant X)	2020 – dairy products	National public ltd	Large	
C	Production manager (company 2, plant Y in different province)	2020 – dairy products	National public ltd	Large	
D	Production manager (company 3)	2834 – pharmaceutical	Family-owned	Large	Interview
E	Production manager (company 4)	2840 – soap, detergents, cleaning preparations, perfumes, cosmetics	Family-owned	Large	
F	Transformation senior staff, in charge of operations (company 5)	2870 – agricultural chemicals	State-owned	Large	
G	Production manager (company 6)	2834 – pharmaceutical	Multinational	Large	
H	Production manager (company 7)	2834 – pharmaceutical	Multinational	Large	Focus group discussion
I	Site operations manager (company 8)	2834 – pharmaceutical	National public ltd	Large	
J	Supply chain manager (company 9)	2834 – pharmaceutical	Multinational	Large	
K	Operations manager (company 10)	2754 – food and beverage	National public ltd	Large	
L	Senior manager (company 11)	3448 – prefabricated metal buildings and components	National public ltd	Medium	

Table 1. The profiles of informants and data collection methods

as "man vs machine" and "let[ting] the machine talk" (respectively). It seems that these three informants related Industry 4.0 to the capability of their production equipment to communicate with each other and provide the company with production data. Informant C interpreted the Industry 4.0 phenomenon as the greater use of ICT for production. To a lesser extent, this perception was similar to that of previous informants. Informants F and G incorporated the Internet in their definition—and in principle, Industry 4.0 uses the IoTs. The informants provided their various definitions of the term "Industry 4.0," but all opinions were comparable and leaned toward the utilization of high technology in production.

Through the in-depth interview, it became clear that most informants had implemented Industry 4.0 initiatives before they learned the jargon. The company of Informant A, for example, developed machines that replaced human operators in 2012 (approximately four years before the informant heard of the Industry 4.0 term). The trigger of this implementation was a series of labor strikes that happened in the plant. The strikes were intense and so frequent that, at one time, the company had to close a plant; this caused a tremendous loss for the company. Informant A decided to develop machines that could replace those laborers specifically to reduce the number of workers in the plant. Before the strike, one piece of equipment was operated by five employees. With the new machines, it was the other way around: one employee worked five machines altogether. It was quite an achievement because not only did the company save on labor expenses, but it also reduced the tension between the

Table 2.
Results of interviews

	Informant						
	A	B	C	D	E	F	G
First heard of Industry 4.0	2016 at the ministry	2016	2016	2018 since the minister of trade visited the plant	2018 thru online media	2017, endorsed by holding company	2018
Have implemented	Yes since 2012	Yes since 2016	Yes	2012 since 2012	Yes since 2018	Yes at the basic level	Yes at the basic level
Perception of Industry 4.0	Machines communicate with server	Man vs machine	The greater usage of ICT for production	Let the machines talk	n/a	Everything can be controlled from afar thru Internet	The internet of things
Triggers	Labor strike and company growth	Difficulty in analyzing productivity (invalid and unreal time data)		Compliance to U.K. requirements	Efficiency	For accurate data and reporting	Efficiency (paperless)
Industry 4.0 programs*	(1) New machines replaced labor (2) Machines sent data directly to control room (3) Face recognition for warehouse	(1) Smart manufacturing project (machine automation) (2) Machine digitalization to capture accurate and real-time data	Machines sent data directly to server (ERP system)	Machines sent data directly to server	(1) Robots replaced workers (2) Machine sent data directly server to production manager, SCM manager, and director	Data tracking thru server: production to distribution	Smart manufacturing project (machine automation)
How to develop Industry 4.0 technology	Mostly in-house	Company's IT and vendor	Company's IT and vendor	In-house (company group)	Mostly vendor	Mostly in-house by holding co	Vendor

(*continued*)

Table 2.

	Informant						
	A	B	C	D	E	F	G
Main challenges**	IT infrastructure and HR	HR and system	Old machine and HR	Limited knowledge, HR, government regulation	HR and QC	Security and HR (building the right culture)	Big investment (funding)
Managerial responses	Benchmark, learning, implement	Explain the change and the benefits to the employees	Change management (intensive communication), training	Champions	Hire supervisor with mechanical engineering background	Change management (change of habits)	Learning (adopting)
Key success factors	Commitment of top management	n/a	n/a	System	Commitment of top management	Enforcement from holding	Commitment of top management
Aim of Industry 4.0 programs	Predictive maintenance thru big data	(1) Real-time data for quick decision making (2) Predictive maintenance	Accurate data for decision making	(1) Compliance and Traceability (2) Productivity (3) Predictive maintenance	Efficiency	(1) Faster response (2) Reduce losses (3) Paperless	Efficiency

Note(s): *Programs were observed through plant visits when applicable
**IT = Information and Technology; HR = Human Resources; QC = Quality Control

	Informant				
	H	I	J	K	L
Perception of Industry 4.0	Interconnection and integration of systems with less manual control	Creating a smart plant, not only automation but also big data to predict the future	Industry 3.0 plus internet-based, company-wide processes	Automation, internet of things, real-time data	Internet of things, web-based processes
Status of Industry 4.0 transformation*	Still in design state	Use of AI and big data on sales and marketing functions	Still in Industry 3.0 phase	Use of AR on marketing function, automation on warehousing and IoT on trucks	Installment of smart machines
Challenges	Human resources			Human resources	
Aim of Industry 4.0 transformation (if any)	Efficiency	Compliance and efficiency		Compliance and forecast accuracy	Efficiency and competitiveness
Would the transformation pay off?	Yes, for data control and review for decision making	Yes, especially for reducing errors	Yes and no. The investment is so huge. Rather skeptical	Yes, for production but not for transportation aspect	Yes, for customized products; but no for standard products

Table 3.
Results of focus group discussion

Note(s): *AI = Artificial Intelligence, AR = Augmented Reality

company and the labor union. Later, Informant A and his team developed a device that connected the machines with the company's server so that the data from each machine could be traced directly from the control room.

Informant E brought up a similar sentiment. Recently, he invested in robots that packed finished goods. Before the utilization of robots, 75 operators worked in that area per day over the course of three working shifts. With the use of robots, the company had to relocate to a sister plant or lay-off these operators. Informant E mentioned that his operators were often undisciplined during their duties, prolonging their break time or leaving work without permission. Therefore, to some extent, Informant E felt relieved that the robots substituted these undisciplined operators. Through the Internet, the robots could send data to the company's server so that Informant E and other appointed managers could read the results on a dashboard.

Informants B and C were from one company group, but each managed a different plant in different provinces. Both informants highlighted the difficulty of analyzing production data as a trigger to implement Industry 4.0 initiatives. They did not realize that this implementation was part of the Industry 4.0 evolution itself. As Informant B stated,

> Actually, the production department does not care whether it is about industry 4.0 or not. They know that the spirit of ICT enhancement is used, and it has been used for a long time.

The company implemented a "Smart Manufacturing" program, in which the machines produced data and sent it directly to the company's ERP (Enterprise Resource Planning)

system through a server. Before the execution of the Smart Manufacturing program, the company recorded all production data manually, leading to human errors and lengthy decision-making time. Now, the company benefits from accurate, real-time data produced by each machine within the plant.

Nevertheless, the Industry 4.0 transformation is not without its hurdles. Informant C argued that automation often caused adjustments that limited the company's ability to improve. Informant C recalled,

> [T]he infrastructure or technology of Industry 4.0 is not as flexible or customized as we imagined. With a manual system, we can set it according to what we need. Still, when we have to buy or use an existing system [as an Industry 4.0 initiative], we have to change many things, so it is not a system that adjusts but instead causes new boundaries that we must adjust. That's a drawback; yes, Industry 4.0 can indeed help us, but on the other hand, there are limits.

Informant D implemented a comparable program at his plant: each machine sent data directly to the manager. He recalled that the first Industry 4.0-related initiative was employed between 2012 and 2015. However, unlike the companies of Informants B and C, this program was core to their customers' requirements. The company exported medical drugs to a UK-based customer, who demands rigorous quality-control data. Without digitalization at the plant, the company could not comply with the customer's requirements, so Informant D and his team (comprised of production, engineering and IT staff) developed a data interface, which enabled the machines to send real-time productivity data to the manager. All data related to the quality check also transferred to the manager. Currently, Informant D was working on a more integrated project in which a group of machines (that belongs to one production line) would be able to send data for further analysis. The data include daily production-line activities, line bottlenecks, as well as priority problems.

All companies used an IT vendor to develop the required technology, except for the companies of Informants A and F. These informants built their own Industry 4.0 technology along with their IT staff. Drawing from these profiles, it became apparent that the ownership of a company did not determine the choice of building in-house or outsourcing; that is, a family business could use either an external party (Informant E) or take advantage of the capabilities of their own IT units (Informants A and D).

Interestingly, even though the Industry 4.0 transformation was highly related to technology, most (six of seven) informants underlined human resources as their primary challenge throughout the Industry 4.0 implementation. Some of their concerns were the limited knowledge of the operators and the resistance to change. The companies had to implement a systematic change management process that consisted of intensive communication, training, campaigns and appointed employees who served as champions. Informant A added top management commitment as one of the critical success factors of the transformation. Informant E seconded this opinion. He further responded to the Industry 4.0 transformation by hiring more subordinates (i.e. supervisors) with mechanical engineering backgrounds, which is notable considering that, instead of dealing with human operators, they are now dealing with robots as operators.

The interviewed informants concluded their conversations with remarks about the overall aim of the Industry 4.0 transformation at their companies. Three themes emerged from their responses: compliance with buyers' requirements, efficiency (faster time, less paper or administration, reduced losses) and productivity (improved decision making and predictability). Furthermore, the informants indicated that they expected these results to enhance the competitiveness of their companies in the market.

Finally, Table 3 presents the results of the FGD. As mentioned in the Methodology section, all informants were aware of the term "Industry 4.0" and thus were able to define it. However, since the Industry 4.0 transformations at their companies were still in the early phases, they

could not report any ongoing projects in detail. Some of them could, regardless, describe their Industry 4.0's benefits and challenges.

All of the FGD informants generally agreed that Industry 4.0 incorporates the Internet in all aspects of the company's processes. They could somewhat explain IoT, Big Data, artificial intelligence (AI) and augmented reality (AR). Informant I acknowledged that her company had implemented AI for Big Data algorithms to aid sales and marketing functions with regard to decision making. Informant K, who works at a large food and beverage corporation, described how their marketing unit designed a service experience using AR for customers to boost the company's sales. Both informants agreed that their company prioritized marketing and sales over production on the Industry 4.0 initiatives.

Informant J stated that her company was currently in an Industry 3.0 phase. That is, the company utilized computers and the Internet but had not extended itself to incorporate Industry 4.0 technology for its manufacturing processes. She was also in doubt about the advantages of Industry 4.0 transformation due to the massive investment that would be required.

Other informants were more optimistic regarding the benefits of an Industry 4.0 transformation. As Informant H stated,

> [Industry 4.0] is especially important for the ease of controlling and reviewing data for further predictions.

Informants I and K also agreed that the advanced technology would make them more compliant with the government standards, facilitate the traceability demanded by consumers and provide more accurate data. They argued that these capabilities were critical for pharmaceutical and consumer goods. Informant L even contended that the technology of Industry 4.0 would improve the company's engineering capacity to design customized products, which, in turn, would enhance its competitiveness in the market.

5. Discussion

The Indonesian government has launched a campaign related to the Industry 4.0 phenomenon so that industries become aware of and gain its benefit to improve their competitiveness in the global market. Its Ministry of Trade actively encouraged manufacturing companies to embrace new technology, such as the IoTs, smart manufacturing and cloud computing.

Findings from the current study indicate that Industry 4.0 was adopted before the informants had even heard of the jargon. Various reasons trigger its initiation, and operations/production managers expect that the upgraded technologies in their factories could improve the companies' productivity. Most of the informants (10 out of 12) are confident that transforming the operations function would lead the company toward a better position in the current market. These findings are further discussed below.

5.1 Implications for literature

Considering the informants' responses, it seems that many companies are at the end of the Industry 3.0 phase and moving toward the beginning of the Industry 4.0 phase. Some of the technologies used have already demonstrated the existence of smart manufacturing technology, as suggested by Cordeiro *et al.* (2019), and described as follows.

Cyber-physical systems (CPS) are one of the core technologies characterized as Industry 4.0 fundamentals (Cordeiro *et al.*, 2019). Informants B, C and D put this into practice by integrating machines on their shop floors with the company's Enterprise Resources Planning (ERP) system—as well as with the top management's dashboard—using IT infrastructure. Previously, their workers had to input the production data manually, but now the data flows

on a real-time basis. The new information updates the ERP system and triggers a computation. The ERP system sends the result back to each machine as an order for production.

The IoT was also implemented when the informants installed a specific panel on their current machines so that they could send performance data directly to the control room. Its concept is interrelated with CPS (Ochoa *et al.*, 2017). Still, IoT specifically connects objects such as robot hands (as in the case of Informant E) so that they could serve as agents and interact with humans using an Internet connection. Informant A mentions the use of radio-frequency identification (RFID) in their finished products as a part of IoT, whereas Informant F describes the installation of a tracking panel on every company's truck so that he can trace and monitor the quantity, temperature and location of products in real time.

The application of *Big Data* is also pursued by the informants, as explicitly mentioned by Informants A, D and G. Their companies are gathering a large quantity of real-time data to help them with their decision-making processes. According to the informants, this technology enables them to obtain accurate data and in large amounts that facilitate data simulation. Informant A described how Big Data collection practices had helped the company during the tsunami disaster in Lombok, Indonesia, in 2018. At that time, the entire factory was swept away and destroyed, but the company was still able to save all its data because it had been stored safely in the cloud.

This story also implies the use of *cloud computing* by the company. The company stores the data on a private server for easy access and distribution of information anywhere. Cloud computing is one of the technologies advised by the government to enhance flexibility and efficiency, as supported by previous studies (e.g. Müller *et al.*, 2018; Cordeiro *et al.*, 2019).

Mostly, the informants agreed that a large amount of data would be useful to build a predictive maintenance system, but this initiative is still in an early phase. At this point, the informants of the current study are still gathering massive data from their production plants. The interconnection between IoT, CPS and Big Data would also enable a factory to be intelligent: that is, it can learn from the accumulated data, analyze, fix issues as well as improve processes (Cordeiro *et al.*, 2019; Frank *et al.*, 2019). The informants aim for this, but they report that they have not reached that level.

Figure 1 summarized the technologies that the informants implemented at their company using a framework proposed by Culot *et al.* (2020). It is a 2 × 2 framework juxtaposing

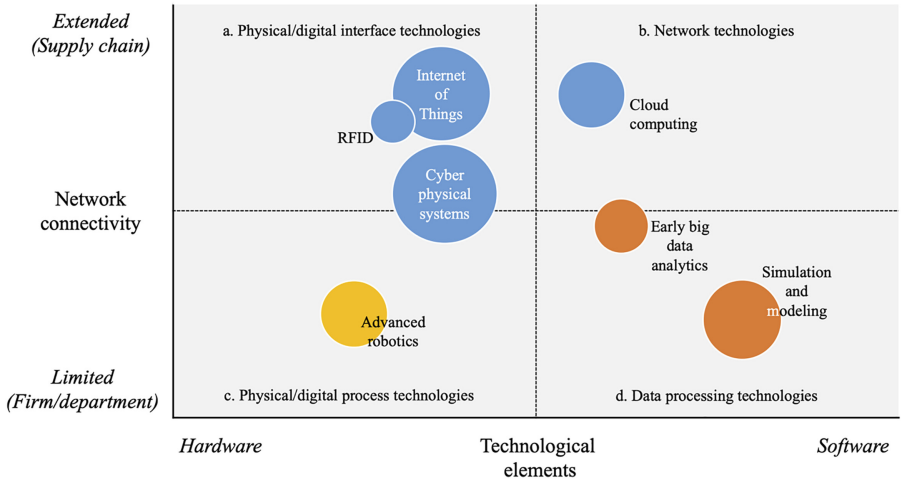

Figure 1.
The enabling technologies adopted by the companies of the current study

technological elements and network connectivity. The bubbles represent an approximation of implementation among the companies. The position might not be precise, as it is a qualitative assessment and does not represent all manufacturing companies in Indonesia; nevertheless, it provides a preliminary picture of the actual adoption of Industry 4.0 technologies in the country.

As can be seen in Figure 1, there is limited adoption of Network Technology (top-right quadrant) by the informants of the current study. Culot *et al.* (2020) proposed that cloud computing, cybersecurity solutions and blockchain technology are part of the software extended across a company's supply chain. Based on our findings, only cloud computing is being adopted by the informants.

The majority of the informants (i.e. 4 out of 7 interviewed managers) are using the assistance of IT vendors to design and implement Industry 4.0 technologies. Yet, the system cannot be immediately ready for use. This challenge is aligned with the findings of Culot *et al.* (2020), who argue that there is no ready-made technology for companies. Furthermore, Birkel *et al.* (2019) discuss the necessity of organizational and technological integration to optimize Industry 4.0 adoption.

Related to the determinants of Industry 4.0 adoption, in his study, Basl (2017) highlights the basis for companies in the Czech Republic to implement Industry 4.0 initiatives. One of the reasons is customer pressure, which applies to Indonesia, especially for companies that export their products to developed countries that pose stricter requirements. Indeed, Industry 4.0 technologies enable companies to support more precise traceability of companies' products, a capability demanded in the pharmaceutical and food industries.

Aside from compliance with the buyers' requirements, informants from the FGD (Informants D, I and K) highlight worker issues as triggers to pursue Industry 4.0 initiatives. Companies are replacing workers with machines or robots in Indonesia, and even though we cannot infer this as a common practice, it occurs nonetheless and is usually effected to gain productivity. In his study of Industry 4.0 in Korea, Sung (2018) suggests the loss of many jobs as a significant impact of this change; this also happens in Indonesia, and more specifically, in the company where the informants work.

Drawing from the findings, the main barrier that most informants have to face is human resources, either in terms of their resistance to change or the skills and talents required for the adoption of Industry 4.0 technology. This finding supports Sung's (2018) and Schneider's (2018) studies. Companies need operators or production employees with advanced skills and competencies to keep up with a smart factory (Schneider, 2018; Veile *et al.*, 2019). Moreover, large investment also hinders the adoption of Industry 4.0, as already cautioned by Moktadir *et al.* (2018) and Birkel *et al.* (2019). Therefore, the implementation of Industry 4.0 is still in the early phase at manufacturing companies where the informants work.

The informants propose solutions to the challenges: the commitment of top management, intensive communication, on-the-job training and champions or supervisors as change agents who could help the employees improve their capability throughout the Industry 4.0 initiatives. Training and education are two essential elements suggested by scholars to enhance the talents and skills of the employees (Erro-Garcés, 2019; Rejikumar *et al.*, 2019; Veile *et al.*, 2019).

All these suggestions represent the managerial responses to the Industry 4.0 transformation. Drawing from Almatrooshi *et al.* (2016), it is a competent leader who supports the employees' training and contributes to the employees' performance, which, eventually, would enhance the company performance. Cultural and leadership aspects were also particularly critical for successful Industry 4.0 implementation (Schneider, 2018). This study offers a conceptual framework as a summary of the findings (see Figure 2).

The proposed framework reveals different determinants that trigger the companies to engage in Industry 4.0 initiatives: labor, data (especially validity and timeliness), compliance

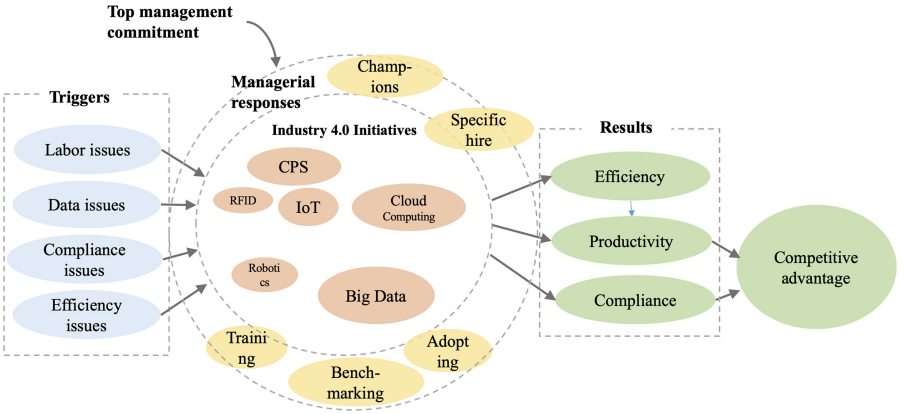

Figure 2.
Conceptual framework of managerial responses to industry 4.0 adoption

and efficiency issues. These factors lead to the operations managers' attempts to solve the problems by improving the technical capability of their machines. Through the Industry 4.0 transformation, the managers have to benchmark best practices, technology adoption, training, as well as appointing champions as change agents and hiring employees with mechanical engineering backgrounds. Even though the transformation takes time, the results are limitless. The essential benefits that the managers have already gained are improved efficiency, increased productivity and requirement compliance, which leads to a competitive advantage for the company.

5.2 Implications for practice

The findings of this study confirm pertinent concepts suggested by scholars, especially in ensuring the effectiveness of the Industry 4.0 initiatives. Aside from the necessary investment for the technology and systems, such as cyber-physical systems, the IoTs, Big Data, cloud computing, as well as robotic and digitized machines, managers need to identify the right skills and competencies for the employees. Training and education become critical in supporting the transformation to instill not only job-related aspects and ICT know-how, but also "soft" competencies such as critical thinking, teamwork, creativity, effective communication and leadership. These soft competencies have become more prominent in the Industry 4.0 era.

Based on the FGD, informants feel wary of the considerable investment required by Industry 4.0 technologies. Some Indonesian companies might not be able to afford the technological infrastructures associated with it, mainly because the majority of Indonesian companies are small and medium enterprises with limited budgets. Operations managers of large companies will benefit from advanced technologies; however, medium enterprises could soon catch up, since the costs of technologies always reduce over time. RFID, as an example, was an expensive technology five years ago, and now medium enterprises can afford to implement it.

This study also confirms that resistance from the employees is an element of the Industry 4.0 transformation that managers have to be attentive. The opposition is not only to layoffs but also to changes in technology used by operators. When CPS, IoT, cloud computing and Big Data analytics are in place, managers might need to train the employees or alter their job specification. Managers should ensure the optimal human resources systems in the company, and—if necessary—make the appropriate transformation. The cultural fit is mandatory.

Overall, the commitment from top management is the key to the success of Industry 4.0 initiatives and to obtain the expected outcomes.

5.3 Limitations of the study and future research

We should interpret the findings with caution. As is the nature of the qualitative method, this study examines a limited number of managers who are currently embarking on a transformation. Albeit offering an in-depth investigation, the findings do not necessarily represent general practices; therefore, more studies related to the Industry 4.0 phenomenon in Indonesia are needed.

Furthermore, this study mainly examines the implementation of Industry 4.0 initiatives of medium-to-large manufacturing companies. On the one hand, this selection is instrumental in allowing more homogeneous samples by reducing the number of control variables (Thomson, 2011); on the other hand, this limits the generalizability of the results. Future studies could enhance the findings by investigating Industry 4.0 from the lens of small-to-medium companies.

6. Conclusion

This study aims to reveal Industry 4.0 phenomena through the lens of operations managers. Using GTM, this study portrays managers' responses to Industry 4.0, their main challenges with Industry 4.0 initiatives and their actions in resolving all issues associated with its implementation.

This study only investigates informants from large companies; thus, its results cannot be generalized to all companies in Indonesia. However, GTM allows researchers to rely on empirical data from the field, as opposed to a given theory created by other theorists. As suggested by GTM, this study can be a reference to understand the empirical facts of Industry 4.0 in a newly industrialized country. The findings capture the actual responses of operations managers in Indonesia in the era of Industry 4.0, their barriers and challenges. This study enriches literature that is predominated by the results of developed countries.

Finally, this study proposes a theoretical framework, which draws a connection between the trigger of Industry 4.0 initiatives, its implementations, challenges and critical success factors, as well as its positive outcomes for the organization. This conceptualization provides a preliminary picture of Industry 4.0 implementation in an NIC and broaden our understanding regarding the implementation of Industry 4.0.

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Appendix

List of questions

Semi-structured interview

(1) (Introduction): Name, Age, Company, Title

(2) What is your scope of work?

(3) Have you heard about Industry 4.0? (If not, mention some characteristics, such as IoT, cloud computing, digitized manufacturing, smart production)

(4) What have you learned about it?

(5) When was the first time you hear about it?

(6) How did the company respond to it?

(7) What did you decide?

(8) What specifically did you do?

(9) What were the changes implemented by the company?

(10) What were the challenges in the implementation?

(11) How did you resolve the challenge?

Focus group discussion

(1) (Introduction): Name, Age, Company, Title

(2) What is your scope of work?

(3) Have you heard about Industry 4.0? (If not, mention some characteristics, such as IoT, cloud computing, digitized manufacturing, smart production)

(4) What have you learned about it?

(5) To what extent does your company plan or implement Industry 4.0 initiatives?

(6) What are the challenges that you foresee?

(7) What would be the benefits of pursuing Industry 4.0?

About the author

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