INDUSTRIAL REVOLUTION 4.0 (IR 4.0) COMPETENCIES: A LITERATURE REVIEW OF MANUFACTURING INDUSTRY

Hussain Matar Mohamed Ghaith Alhosani, Universiti Teknikal Malaysia
Amiruddin Ahamat, Universiti Teknikal Malaysia
Norain Ismail, Universiti Teknikal Malaysia

ABSTRACT

Manufacturing industries are different from what they were a decade ago due to challenges related to IR 4.0. The main challenges are associated with the lack of leadership, knowledge, and talent workers; all are linked to the competencies needed for the workers in the Era of IR4.0 manufacturing industry. Therefore, this study investigates the landscape of the required competencies by exploring the previously published articles. This study is based on an illustration of a literature review to provide a comprehensive IR4.0 competency model for manufacturing industries. The proposed model illustrates a total of 64 skills and competencies, which can be classified into twenty classes on the second level. A higher level can classify it into eight classes based on the SHL competency classification approach. The results indicate that many behavioral competencies should be conformed through all workers, such as decision-making. It implies that workers of the future ought to successfully carry a higher level of behavioral competencies to work in Industry 4.0. Only competencies under the dimension "Applying Expertise and Technology" have three variants of advanced technology-based components. These variations are allocated into three categories; information system, computer science, and engineering focusing on manufacturing industries. Thus, competencies such as interdisciplinary working, collaboration, interaction, or teamwork will have a distinctive function.

Keywords: Competencies, Industry Revolution 4.0, IR4, Manufacturing Industry

INTRODUCTION

Technology has become more advanced than ever, and companies can now produce items and interior solutions that were difficult to envision a decade ago (Urbinati, Bogers, Chiesa & Frattini, 2019). The manufacturing industry markets may have been behind on keeping up with all those innovations. Nevertheless, their leaders cannot dismiss the progress that the fourth commercial revolution is making anymore (Koizumi, 2019). The new industry 4.0 techniques include IoT, big data, and artificial intelligence. They are poised to transform the entire value chain within the manufacturing market. The importance of industry 4.0 is related to its benefits, which include assisting manufacturers in overcoming challenges by being more adaptable and learning how to respond to the continuous adjustments in the marketplace efficiently. It can also enhance innovation speed, make the design procedures faster, and develop a customer-driven system (Koizumi, 2019).

The globe is continually evolving; however, it's challenging to comprehend how much things have changed fully. Today's manufacturing is nothing like it was ten years ago. Technology is upgrading the environment and making workers trained and qualified to be more valuable than ever before (Koizumi, 2019). Nowadays, the manufacturing field is transforming jobs into professions and sustaining progress for the business itself and its employees (Bakhshi, Downing, Osborne & Schneider, 2017). In response to new technology, manufacturing jobs are evolving away from routine and repetitive work and toward more skilled, diverse positions. As

companies continue to evaluate how technology fits into factories, they will also need to ensure that they can attract, retain, and develop workers with the necessary skills for these new roles (Sihlongonyane, Ndabeni & Ntuli, 2020).

Manufacturing education has been facing many challenges because of the emergence of IR 4.0 in manufacturing. New skills are required immediately to be mapped with the unique requirements of knowledge-based manufacturing. The manufacturing education should be interested in the continual provision of incorporated engineering competencies and rich multi-disciplinary background. Therefore, the approaches, the adaptation of the training content, and delivery mechanism must be developed (Bakhshi et al., 2017). Besides, a manufacturing approach concentrating on digital business and extended production should be considered (Camarinha-Matos, Fornasiero & Afsarmanesh, 2017). On the other hand, there is an increasing need to make technological advancement and skills unified worldwide to facilitate the global environment and key manufacturing-oriented actors (Camarinha-Matos et al., 2017).

Managing innovation and creativity at the organizational level is problematic because, at the current phase of the Industry 4.0 evolution, 50% or more of manufacturers acknowledge that the execution barricades are reliable, which only allowed to attain minimal improvement with their industry 4.0 projects in the course of last year (Camarinha-Matos et al., 2017). The reasons behind this lack of IR 4.0 adoption include data security and ownership, difficulties in integration and mitigation between old and new systems, lack of knowledge, lack of unified leadership, and lack of creative workers (Camarinha-Matos et al., 2017). Some of these factors are linked to the shortage of knowledge and skills of the workers; such as the shortage of unified management that makes cross-unit management hard within the company, lack of internal skill to support the advancement and release of Industry 4.0 efforts, and lack of knowledge concerning innovations and IT outsourcing partners that could aid in executing core IR4.0 operations (Bawany, 2019; Bragagnolo, 2017).

Manufacturing industries are different from what they were one decade ago because of the challenges related to IR 4.0. The main challenges are associated with the lack of leadership, knowledge, and talent workers; all are linked to the competencies needed for the workers in the Era of IR4.0 manufacturing industry. Therefore, this study investigates the landscape of the required competencies by exploring the previously published articles.

METHODOLOGY

This study is based on an illustration of the literature review to provide a comprehensive IR4.0 competency model for manufacturing industries. One of the essential first steps when working on a research project is the literature review because knowledge is created by combining and interpreting existing knowledge (Hensel & Nilsson, 2019). Therefore, to prepare a theoretical basis for this study, the chosen research method is the literature review.

An organized literature review that supplies a thorough perspective of existing research results is applied and followed by a principle-centric approach to identify and summarize competencies concerning Industry 4.0 and a focus on manufacturing industries shown in the literary works. To conceptualize the topic, a great number of literary works was considered by dividing the research scope "Competencies for Industry 4.0 in manufacturing industry" into two parts which are, "Competencies for manufacturing industry" and "Industry 4.0". For each of these parts, a search through literature works was done to define basic synonyms or similar concepts for conceiving the topic. The following concepts with regards to Industry 4.0 could be defined: "Industry 4.0"; "Industry 4.0"; "Digital Transformation"; "Internet of Things"; "IoT"; "Cyber-Physical Systems"; "CPS". Further, the following concepts with regards to competency were defined as: "competence", "competency"; "skill"; "knowledge"; "attitude"; "ability"; "value"; "education".

The database search included ACM journals, IEEE journals, ACM conferences, IEEE conferences, Springer library, Ebsco Host library, and other international conferences. Besides, Google Scholar was used to searching for articles that have not been published and relevant to

the current research. The results from the Google Scholar search were sorted based on the level of importance. By the end, we considered the top 30 articles. This research study's time range is up until 2019/2020, emphasizing research from the recent five years. In the end, we found a total of 27 articles that include both scientific and practitioners' articles.

LITERATURE REVIEW

Industry Revolution 4.0

The Fourth Industrial Revolution or Industry 4.0 is an umbrella term that refers to modifications in the industrial value chain process. Those modifications become stronger by emerging technologies and by providing better techniques to arrange and handle regular procedures (prototyping, progression, production, coordination, supply etc.) within the manufacturing industry (Culot, Orzes, Sartor & Nassimbeni, 2020). In short, it involves all the additional computerization firms now deploy to increase their manufacturing cycles and combine various aspects of work into a linked digital ecosystem (Bragagnolo, 2017). The use of technology in the industry is associated with evolution 3.0, in which automation, computers, and electronics characterized this stage (Bawany, 2019; Bragagnolo, 2017). Nonetheless, the new digital systems, materializing as part of Industry 4.0, instrument data for both physical and digital resources through emerging Industrial IoT tools; Robotics resources and autonomous robots; Big Data analytics devices; Artificial Intelligence and Cognitive systems; and Augmented Reality (Zheng et al., 2018). The significant difference between the current and the previous stage is that these digital technologies strengthen the physical part of development, production, distribution, and performance within one ongoing Physical-Digital-Physical (PDP) round (Đuričin & Herceg, 2019).

Within this PDP cycle, real-time information and intelligence flow in between physical and digital components of the manufacturing procedure. The essence of Industry 4.0 constitutes the connection between digital technologies encouraging action in real life. Industry 4.0 has four characteristics, further associated with many business processes that chose to pursue Industry 4.0. Horizontal connections through a new generation of global value chain systems. The Physical-Digital-Physical (PDP) cycle allows a higher degree of transparency. It also will enable organizations to situate and deal with problems faster. Such organization-wide networks can record details from all the procedures, including intra logistics and warehousing, to prototyping and production, to marketing and sales to downstream services. Every element of every method is logged and can be analyzed and considered at any time (Bartodziej, 2017; Otles & Sakalli, 2019).

Vertical connections facilitate the digital-to-physical processes and allow a fast response from manufacturers to changes resulting from changing requirements, stock levels, or sudden equipment failings. Smart factories are considered positively linked entities by various systems that allow those factories to communicate and modify their performance (Bartodziej, 2017; Otles & Sakalli, 2019). Through engineering across the entire value chain. The development and manufacturing activities of each product are organized and combined with the product life cycles. New synergies emerge between product development and manufacturing units (Bartodziej, 2017; Otles & Sakalli, 2019). Acceleration through exponential technology. Creating a highly autonomous and cognitive ecosystem is one of the anchors of Industry 4.0. It depends on machine learning, deep learning, advanced robotics, and commercial IoT to speed up efficiency (Bartodziej, 2017; Otles & Sakalli, 2019).

Challenges of Industry Revolution 4.0

Industry 4.0 is a brand new standard of hooked up and digitized manufacturing. It participates in a significant part in changing well-known manufacturing plants into smart and self-governing manufacturing. Typically, Industry 4.0 produces a lot of brand new options for

firms; however, all at once, numerous difficulties are emerging coming from the continuous hands-free operation and digitization (Butt, 2020). Industry 4.0 is a sight for the future because it entails several components and encounters numerous forms of difficulties and troubles, featuring technological obstacles, economic challenges, political concerns, and social issues (Zhou, Liu & Zhou, 2015).

Social Challenges

Some of the critical influencing challenges are social problems, including demographic improvement, worker qualifications, digital skills, and new modern technologies. Shortage of digital culture and skills and skills are the main obstacles from the employees' perspective. Companies require to bring in, retain, and qualify their employees who are comfortable doing work in a vibrant ecological community. Business' effectiveness, along with Industry 4.0, will depend upon their staff members' skills and knowledge. The most significant constraint might be helping and supporting the workforce needed to place digitization into the workplace (Rawlinson, 2019). The current work in manufacturing deals with a high risk of being automated to a considerable extent because the jobs will be decreased. Keeping manufacturing jobs will include even more knowledge and more hard-to-plan and temporary duties. The employees significantly have to monitor computerized devices. The decision-making method is necessary to be decentralized since all staff members should participate in design tasks as an end-to-end design aspect. In the short term, the trend towards more significant computerization will remove several of the often low-skilled workers who conduct easy, repeated tasks (Rawlinson, 2019).

Simultaneously, the increasing use of software applications, connectivity, and analytics will undoubtedly improve the demand for workers and competencies in software program growth and IT modern technologies. New task profiles, along with novel requirements for instruction and learning, are expected to emerge and reduce the relevance of manual work instead of IT-skills. Additionally, procedures are even more intricate, which brings about an increase of work with more essential qualifications and a loss in projects requiring lesser credentials. Therefore, providers need to certify their workers for an additional key, teaming up, and imaginative tasks along with more significant accountabilities (Rawlinson, 2019).

Economic Challenges

Concerning the ongoing globalization approach, firms have to reduce time-to-market, much shorter item lifecycles, and the necessity to cut prices to keep reasonable. Furthermore, markets have ended up being heterogeneous and considerably unpredictable. Industry 4.0 practices have several obstacles and occur in a vibrant, affordable environment. The features of Industry 4.0 re-design the industry boundaries, creates entirely brand-new industries and reveals reputable manufacturing providers to new reasonable challenges (Jackson, 2020). Subsequently, the need for cooperation is an essential matter now and cannot survive without effective networking. The business currently has to enter into crucial collaborations with their suppliers or competitors to remain competitive. That leads to the relationship of entire market value chains, and therefore, raises the complexity of processes and monetary constraints (Goerzen, Iskander & Hofstetter, 2020).

Technological Challenges

Digital connectivity indicates the sharing of data and opening up to a competitive market atmosphere, causing straightforward company ecosystems that are mainly helped with online systems. Appropriately, companies need to handle two issues. A very high degree of clarity reveals companies to the risks of cyber-attacks and industrial snooping, and the obstacle of protecting data civil liberties and gain access to (Krämer & Wohlfarth, 2018). Second, a business that establishes system standards might hinder the working contemporary business

solutions for repositories and finally steer them away from the marketplace. Various other difficulties describe the shortage of global requirements and data discussing the process and inadequate existing data premium. To deal with these difficulties, historians recommend providers to demonstrate and methodically introduce their current company models (Krämer & Wohlfarth, 2018).

Political Challenges

Political problems describe legal concerns and issues of synchronization and partnerships. Federal governments need to support institutions and the progression of innovations and integrate those technological devices in the existing environment. Moreover, governments must develop lawful specifications for the use of big data, considering that one of the essential concerns is privacy, and data compilation will be crucial while socializing with smart devices. Developing work flexibility further demands policies for job opportunities and security to guard workers (Wang, 2018).

Skills and Competencies

Two of the main building blocks of any learning process is skills and competencies (Figure 1). Skills are specific learning activities that require abilities or mastery cultivated through training (Sanghi, 2016). In the business domain, a skill is a physical task that helps perform one or more of the job assignments. Skills allow to apply knowledge and use proficiency for finishing well-defined tasks. In general, it recognizes that a person can perform within a specific circumstance (Ala-Mutka, 2011; Sanghi, 2016). Skills can be intellectual (meaning that it involves the use of thinking styles) or practical (entailing physical dexterity and making use of materials, techniques, and tools) (Mäkiö-Marusik, 2017; Mäkiö-Marusik, Ahmad, Harrison, Mäkiö & Walter, 2018).

FIGURE 1
SHILLS AND COMPETENCIES

McClelland (1973) was the first to define competencies; the author stated a competency as "A personal quality that results in a high quality or more effective performance". A competency is a collection of skills, capabilities, and knowledge that permit an individual to perform appropriately in a job. From a business perspective, competencies describe the skills, abilities, as the knowledge that every individual needs to complete a task (Jerman, Pejić Bach & Aleksić, 2020; Oberländer, Beinicke & Bipp, 2020). Competence is the individual's ability to

manage a specific scenario or perform a task properly. This ability might be related to cognitive factors (e.g. different kinds of knowledge), perceptual and intellectual leadership skills (e.g. dexterity), efficient factors (e.g. behaviors, values, motivation etc.), personality traits (e.g. confidence), and social skills (e.g. communicative and participating skills) (Jerman, Pejić Bach, et al., 2020).

Competency Models

A competency model is a compilation of competencies that, when put together can determine effective performance in a particular job environment. These competency models are the base for substantial HR tasks such as hiring, training and development, and managing performance (Campion et al., 2011; Stevens, 2013). Over the years, several competency models have been developed. One of these models is the basal theory of Erpenbeck & Von Rosenstiel (2007). This basic model mapped between theory and practice. The model identifies four competence-classifications, which are (A) activity and realization orientated, (P) personal, (S) social-communicative competencies, and (F) specialized-methodical. In addition to competence-types advancement and gradient strategies (Figure 2).

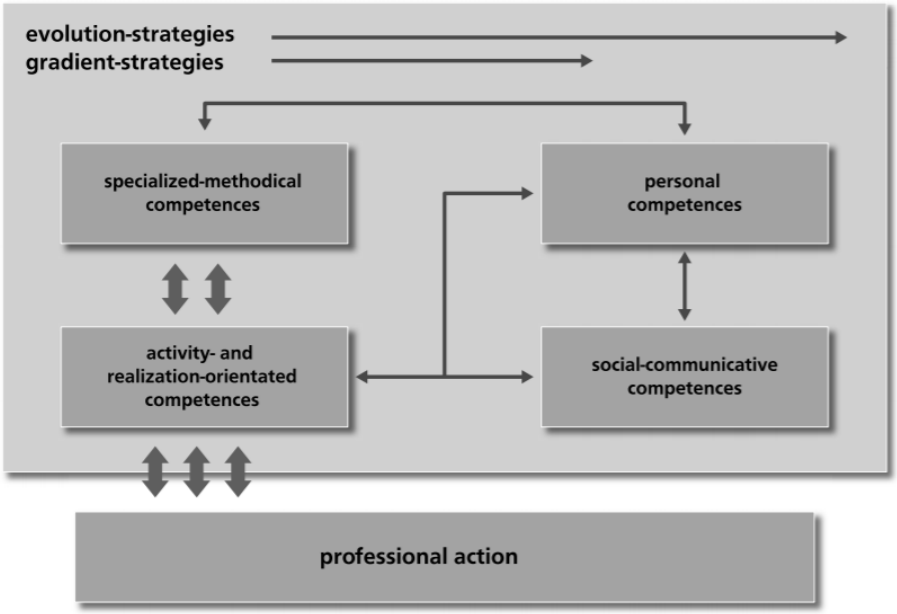

FIGURE 2
MODEL OF COMPETENCIES REFERRING TO Erpenbeck & Rosenstiel (2007)

Egeling & Nippa (2009) added another classification by dividing competencies into meta, method, domain, and social competencies. Additional competency models have been designed for leadership and management (Prifti, Knigge, Kienegger & Krcmar, 2017). CEB Inc. (2016) is a leading international company that provides a comprehensive Universal Competency Framework (UCF) known as SHL competency framework. The model is designed based on behavioral-based orientation and was derived by analyzing practitioners and academic approaches. It includes three hierarchical levels, starting with the "Great Eight" as the first level that assists work performance and defines the eight primary groups of competencies. The second level is composed of twenty competency dimensions that further divide these eight groups into additional categories. The third level is comprised of 112 element competencies. All of the available competencies are explained at this level, and each one may be matched at any of the 112 components (Figure 3).

FIGURE 3
UNIVERSAL COMPETENCIES FRAMEWORK (shl.com, 2020)

This model gives a detailed level of information. This framework provides an overview of competencies, which allows the development of competency models for specific topics. For this particular study, the proposed model is adapted using the "Great Eight" as the first level and the twenty competencies dimensions as the second level. However, the third level is accumulated through published articles and literature reviews. The proposed competency model is adapted for the required competencies at the behavioral and IR4.0 requirements (Bartram, 2012). Choosing the SHL universal competency model as a foundation for this research contributes to the linkage between practice and academic knowledge. Companies commonly use the model to develop their competencies schema and HR practices (Hensel & Nilsson, 2019).

Previous Studies in IR4.0 Competence Framework

Some recent studies try to propose other industry revolution 4.0 competencies framework. Some of it is comprehensive and general, and others are oriented or adapted to a specific domain. The following is an illustration of some recently proposed frameworks for IR 4.0 competencies. Fitsilis, Tsoutsa & Gerogiannis (2018) conducted a study to present an initial competence model to respond to the need for comprehensive competence and skills model for IR4.0 in the industry. The developed model considered into account that "there is no 'technological determinism, there is need to address different skills needs according to the specific Industry 4.0 'biotopes,' there are different workforce segments, various sectors are using different subsets of the technologies under consideration, there are various product lifecycles according to which additional development and operation processes need to be supported". The identified skills are classified as "technical, behavioral and contextual". Technical skills are nine technological areas that are energetic growths in Industry 4.0 advantages. These key technologies are "Big data and analytics; Autonomous robots; Simulation; Horizontal and vertical system integration; The industrial Internet of Things; Cybersecurity; The cloud; Additive manufacturing; Augmented reality". Contextual skills are related to the industry's specific production practices, standards, guidelines, and organizational structure.

These processes may be allocated to management processes or production processes. Business Planning and Logistics are examples of management processes, and product design is an example of production processes. Transversal skills refer to "Skills that are typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge and that can be used in a wide variety of situations and work settings (for example, organizational skills)". This contains personal competencies, social and interpersonal competencies, action-related competencies, and methodological competencies. Decision making

and analytical skills are examples of methodological competencies (Fitsilis, Tsoutsa & Gerogiannis, 2018).

Flores, Xu & Lu (2020) conducted a study to "raise and address an important change for the human capital in the future of Industry 4.0, and to propose a human-focused perspective for companies underneath the new Industrial Revolution". One of the objectives is to propose a framework for the inclusion of the Industry 4.0 organizations' competencies. The taxonomy of competencies is based on analyzing the information from other research done by Hecklau, Orth, Kidschun & Kohl (2017). The proposed framework has 14 essential competencies and five main dimensions; soft workforce, challenging workforce, cognitive workforce, intelligent, emotional workforce, and the digital workforce. The dimension of soft workforce competence includes flexibility and social; these skills are "communication, teamwork or cooperation, leadership, willingness to learn, self-development, negotiation and flexibility or adaptability". The dimension of hard workforce competence includes skills professional and dexterous; The pool covers "industrial organization, industrial processes, standards understanding, problem-solving techniques, designing with software, human-machine interactions, digital network settings, digital security, and coding or programming."

The dimension of cognitive workforce competence includes the skills of intelligence and analytical. Within this category, skills are divided into three facets: facet one, "verbal aptitude (*i.e.*, vocabulary, spelling, and reading)," facet two, "numerical aptitude (*i.e.*, math, arithmetic)" and facet three, "spatial aptitude (*i.e.*, coordination, memory, decision-making, problem-solving thinking, abstract reasoning, and analytical thinking)." The dimension of emotional intelligent workforce competence includes self-awareness and empathy; the skills have "self-awareness, self-control, positive outlook, empathy, achievement orientation, and motivation." The dimension of the digital workforce competence includes skills of digital literate and digital interaction; the list consists of "programming, cybersecurity, digital networks, cloud computing, databases, web development and also the management of Industry 4.0 technologies (*i.e.*, IoT, big data analytics, 3D printing, simulation, augmented and virtual reality)" (Flores, Xu & Lu, 2020).

Simic & Nedelko (2019) provides a comprehensive framework for employees' competencies in the IR 4.0 era. The proposed results are based on critical analysis for recent relevant studies. The authors revealed four categories of competencies; social competencies, personal competencies, managerial competencies, and professional competencies. Social competencies include the following; "building a relationship, sharing knowledge and experience identification with the company, communication, customer orientation, teamwork/team collaboration, solving the conflict, cooperation within the company, and exert influence."

Personal competencies include the following; "pursuit of results (entrepreneurship) innovativeness and flexibility, analytical thinking, self-reliance, decision-making, troubleshooting, thoroughness/reliability, professional development/ readiness to learn, and managing each other." Managerial competencies include the following; "building an efficient organization team building, ability to delegate, motivating, strategic thinking, planning, leadership, project management, and team management." Professional competencies include the following; "administering/maintaining documentation, negotiating, orientation in business, procedures – knowledge and application, IT skills, technical skills, professional knowledge, process management, and knowledge of foreign languages" (Simic & Nedelko, 2019).

Hecklau, et al., (2017) conducted a study funded by EU H2020 within the project "Excellence Center for Production Informatics and Control" to examine the IR 4.0 revolution's influence on the employees' competencies. The study makes a critical review of 12 studies chosen from a different location in the world. The proposed framework called "job-specific and job family competencies," are a cross-classification approach from three levels. At the highest level, all competencies should be either behavioral (cognitive, social, and personality) or technical (know-how). At the second level, the behavior could have motivation, attitudes, and abilities; and technology could have skills and knowledge. There are four categories, personal,

domain, social, and methodological, at the third level, which can be allocated to more than one of the higher levels. One sill can be assigned to more than one category.

The job-family framework is a comprehensive approach that interrelates all the common competencies that logically related to the majority of a career path at IR 4.0 organizations; thus, every employee within the job family shares these competencies. Behavioral competencies are the majority of the skills. However, employees have no choice, and without the technical competencies, they can not perform their job in IR4.0 organizations. In particular, the category of social competencies include Communication, cooperation, and leadership; the category of methodological competencies include analytics, complex problem solving, and decision making; the category of personal competencies include creativity, willingness to learn, and flexibility and adaptability; the category of social competencies include digital networks, digital security, coding, process understanding, and interdisciplinary competence (Hecklau et al., 2017).

Bermúdez & Juárez (2017) conducted a study to identify the required operational management personnel competencies at automotive part suppliers in Nuevo Leon to generate a transition for Industry 4.0. The qualitative results from interviewing 15 managers from 10 operational managements revealed that IR4.0 competencies are allocated into four dimensions; information and communication technologies, Innovation management, organizational learning, and environment. Dimension one is related to "the knowledge and management of software and interfaces that support operations management (resources, people, production)". Dimension 2 is connected to "knowledge and management of simulation systems." Dimension 3 is related to "develop in the employees' skills, capacities, and processes of improvement". And dimension four is connected to "creativity in designing strategies to introduce new practices". Additional competencies had been suggested from the interviewees and found to be relevant; "leadership skills, financial analysis skills, and critical and disruptive thinking" (Bermúdez & Juárez, 2017).

Grzybowska & Lupicka (2017) conducted a study to provide a framework for contemporary managers' competencies to deal with the new challenges of the IR 4.0 revolution. The study does an empirical survey for managers in the automotive industry. The result revealed eight essential competencies, which are supposed to be possessed by contemporary managers to deal with the new challenges of IR 4.0. Those competencies are creativity, entrepreneurial thinking, problem-solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation. This study is specific to managerial skills only. The technical skills were not explored because the study focuses only on the manager's level (Grzybowska & Łupicka, 2017).

Sakuneka, Marnewick & Pretorius (2019) conducted a study to provide a specific competencies framework for control system engineers that fit with the IR 4.0 requirements. The study makes a critical analysis of 18 relevant previous studies. Authors can identify 69 relevant competencies to IR4.0, but the majority are multi-disciplined competencies. The specific discipline competencies to control system engineers are 15 and include the following; computer programming (coding) skills, CPS development, and testing, Data processing analytics (Big Data), digital competency, embedded software design, humanities, IT technical abilities, modern IT solutions capabilities, negotiation, network technology competency, new technology competency (3D, IoT), new-media literacy skill, radio technology competency, robot control *via* production servers, robot programming abilities, sense-making skill, transmission technology competency, virtual collaboration competency (Remote), working with modern interfaces. This study is specific to technical-based competencies; the revealed that nine competencies are completely new to the current competencies framework of control system engineers, and the other ten competencies have partly existed before. However, the study provides a list of the competencies gap to the existing framework and include the following; advanced programming, new technology e.g. CPS, new technology e.g. big data analytics, new technology and devices, advanced control *i.e.*, coding, humanities, advanced programming, evolving technology, negotiation, New technology e.g. Zig Bee, Evolving technology e.g. IPv6, cloud computing, new technology e.g. NFC, robot control *via* production servers, robotics programming, and other modern technology use competencies (Sakuneka, Marnewick & Pretorius, 2019).

Results of Literature

Based on the literature review, 64 competencies are considered applicable for manufacturing Industry 4.0 (Figure 10). These competencies are primarily behavioral through emphasizing the significance of behavioral competencies for Industry 4.0. As mentioned by several authors, one of the main required competencies is communicating (Álvarez Gil, Rosillo Camblor, Ponte Blanco, & López Brugos, 2018; Ansari, Erol, & Sihn, 2018). While behavioral competencies are essential in IR4.0, but the use of technology competencies is the core. The identified competencies of technology are illustrated in Table 1, along with the support from literature articles.

Table 1
TECHNOLOGY COMPETENCIES

Competence	Source
IT and technology ability	(Hizam-Hanafiah, Soomro & Abdullah, 2020; Olojuolawe & Amin, 2019)
Economics knowledge	(Ling, Hamid & Te Chuan, 2020; Olojuolawe & Amin, 2019)
Ability to use social media	(Bahri, Waremra, Reski, Silubun & Rettob, 2019; Ratano, 2018)
Service orientation and product service offerings	(Jerman, Bertoncelj, Dominici, Bach & Trnavčević, 2020; Mourtzis, 2018)
Business process	(Fareri, Fantoni, Chiarello, Coli & Binda, 2020; Jerman, Bertoncelj, et al., 2020)
Change management	(Fareri et al., 2020; Mourtzis, 2018)
Digital security data and network	(A. A. Ismail & Hassan 2019; Kazancoglu & Ozkan-Ozen, 2018)
Integrating heterogeneous technologies	(Hernandez-de-Menendez, Díaz & Morales-Menendez, 2020; Prifti et al., 2017)
Mobile technologies	(Hecklau et al., 2017; Widayani, Astuti & Saifi, 2020)
Embedded systems and sensors	(Hernandez-de-Menendez, Morales-Menendez, Escobar & McGovern, 2020; Widayani et al., 2020)
Network technology and M2M communication	(Fareri et al., 2020; Ismail & Hassan, 2019)
Robotics and artificial intelligence	(Fitsilis et al., 2018; Jerman et al., 2020)
Modelling and programming knowledge	(Hernandez-de-Menendez et al., 2020; Simic & Nedelko, 2019)
Cloud computing and cloud architectures	(Flores et al., 2020; Ismail & Hassan, 2019)
Database knowledge	(Fitsilis et al., 2018; Sakuneka et al., 2019)
Statistics	(Hernandez-de-Menendez et al., 2020; Hernandez-de-Menendez et al., 2020)
Big data analytics	(Ismail & Hassan, 2019; Sakuneka et al., 2019)

For employees and workers after the revolution of IR4.0, they must possess a different set of competencies that are related to the interdisciplinary work environment, international, and dynamic environment, such as the following competencies in Table 2.

Table 2
INTERDISCIPLINARY WORK ENVIRONMENT COMPETENCIES

Competence	Source
Working in interdisciplinary environments	(Cerezo-Narvaez, Otero-Mateo & Pastor-Fernandez, 2017; Grzybowska & Łupicka, 2017)
Flexibility	(Flores et al., 2020; Hernandez-de-Menendez, Morales-Menendez, et al., 2020)
Adaptability	(Bermúdez & Juárez, 2017; Hernandez-de-Menendez et al., 2020)
Innovation	(Jerman et al., 2020; Mourtzis, 2018)
Creativity	(Jerman et al., 2020; Olojuolawe & Amin, 2019)
Critical thinking	(Ismail & Hassan, 2019; Olojuolawe & Amin, 2019)

Life-long learning	(Jerman, Bertoncelj et al., 2020; Ling et al., 2020)
Knowledge management	(Graczyk-Kucharska, Szafranski, Golinski, Spychala, & Borsekova, 2018; Simic & Nedelko, 2019)
Business strategy	(Graczyk-Kucharska et al., 2018; Widayani et al., 2020)
Business models	(Bermúdez & Juárez, 2017; Sakuneka et al., 2019)
Entrepreneurship	(Grzybowska & Łupicka, 2017; Hernandez-de-Menendez, Morales-Menendez, et al., 2020)
Work-life balance	(Cerezo-Narvaez et al., 2017; Hernandez-de-Menendez, Díaz, et al., 2020)
Self-management and organization	(Bermúdez & Juárez, 2017; Ksenofontova, Emtseva, & Khayrova, 2020)
Planning and organizing work	(Bermúdez & Juárez, 2017; Ksenofontova et al., 2020)
Legislation	(Cerezo-Narvaez et al., 2017; Stasiak-Betlejewska & Sujanová, 2020)
Safety awareness	(Cicek, Akyuz & Celik, 2019; Stasiak-Betlejewska & Sujanová, 2020)
Individual responsibility	(Flores et al., 2020; Graczyk-Kucharska et al., 2018)

No doubt that IR4.0 will increase the complexity of work environments; therefore, employees must have analysis competencies and make decisions such as the following competencies in Table 3.

Table 3
ANALYSIS AND MAKING DECISIONS COMPETENCIES

Competence	Source
Problem-solving	(Bermúdez & Juárez, 2017; Jelonek, Nitkiewicz & Koomsap, 2020)
Analytical skills	(Fitsilis et al., 2018; Hecklau et al., 2017)
Cognitive ability	(Chen, 2020; Graczyk-Kucharska et al., 2018)
Managing complexity	(Flores et al., 2020; Graczyk-Kucharska et al., 2018)
Abstraction ability	(Mulyani & Djatmiko, 2019; Stasiak-Betlejewska & Sujanová, 2020)
Decision making	(Bermúdez & Juárez, 2017; Stasiak-Betlejewska & Sujanová, 2020)
Taking responsibility	(Ksenofontova et al., 2020; Simic & Nedelko, 2019)
Leadership skills	(Cerezo-Narvaez et al., 2017; Mdluli & Makhupe, 2017)
Respecting ethics	(Chen, 2020; Liboni, Cezarino, Jabbour, Oliveira & Stefanelli, 2019)
Environmental awareness	(Kaur, Awasthi & Grzybowska, 2020; Ksenofontova et al., 2020)
Awareness for ergonomics	(Grzybowska & Łupicka, 2017; Kadir, Broberg & da Conceição, 2019)

IR4.0 is essential in enriching networking and integration; therefore, it is crucial to have communication competencies such as the following illustration in Table 4

Table 3
ANALYSIS AND MAKING DECISIONS COMPETENCIES

Competence	Source
Problem-solving	(Bermúdez & Juárez, 2017; Jelonek, Nitkiewicz & Koomsap, 2020)
Analytical skills	(Fitsilis et al., 2018; Hecklau et al., 2017)
Cognitive ability	(Chen, 2020; Graczyk-Kucharska et al., 2018)
Managing complexity	(Flores et al., 2020; Graczyk-Kucharska et al., 2018)
Abstraction ability	(Mulyani & Djatmiko, 2019; Stasiak-Betlejewska & Sujanová, 2020)

Decision making	(Bermúdez & Juárez, 2017; Stasiak-Betlejewska & Sujanová, 2020)
Taking responsibility	(Ksenofontova et al., 2020; Simic & Nedelko, 2019)
Leadership skills	(Cerezo-Narvaez et al., 2017; Mdluli & Makhupe, 2017)
Respecting ethics	(Chen, 2020; Liboni, Cezarino, Jabbour, Oliveira & Stefanelli, 2019)
Environmental awareness	(Kaur, Awasthi & Grzybowska, 2020; Ksenofontova et al., 2020)
Awareness for ergonomics	(Grzybowska & Łupicka, 2017; Kadir, Broberg & da Conceição, 2019)

Table 5
ANALYSING AND INTERPRETING COMPETENCIES

Competency Dimension	Competencies
Writing and Reporting	Targeted/Technical Communication Literacy
Analysing	Cognitive ability Optimization Problem solving Analytical skills
Applying Expertise and Technology	**Computer science** Machine Learning It Architectures Network Security
	Information system Understand and Coordinate Workflows Business Process Management Business Change Management Service Orient Informational/ Product Service Offerings **General** Big Data/ Data Analysis and Interperetation Statistics Economics It and Technology Affinity Cloud Computing/ Architectures Extract Business Value from Social Media In-memory dbs Modelling and Programming Data security **Engineering and technology** Mobile Technologies Network Technology/M2m Communication System Development Integrating Heterogeneous Technologies Predictive Maintenance Sensors/ Embedded Systems Robotics/ Artificial Intelligence

The Competency Model

The proposed model describes 64 competencies, which can be classified into the twenty dimensions in the second level. Then they grouped into a higher level of eight categories based on the SHL competency framework. Figure 4 describes the design of the competency framework.

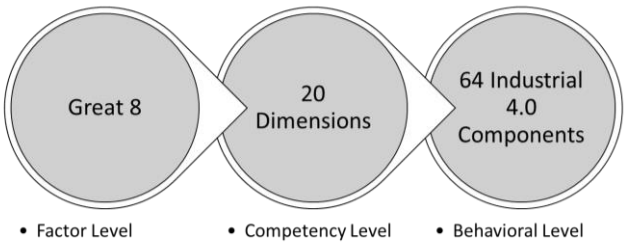

FIGURE 4
IR4.0 STRUCTURAL COMPETENCY MODEL BASED ON SHL APPROACH

The results showed that all employees need to adapt to behavioral competencies, such as teamwork or Decision Making. This implies that in the future and regardless of their position, employees need to bring a higher level of behavioral competencies to succeed in working in Industry 4.0. Only competencies under the dimension "Applying Expertise and Technology" have three variants of advanced technology-based components that are allocated into three categories; information system, computer science, and engineering; which is more focused on manufacturing industries. This dimension represents the knowledge domain. Therefore, each employee should offer different competencies depending on the domain. This shows that Industry 4.0 operations will be connected. Thus, interdisciplinary working, collaboration, interaction, or teamwork will possess an important role.

Manufacturing industries are not limited to technical workers as it includes employees from different specialties and different managerial roles. Therefore, employees in the era of IR 4.0 should inherit different competencies. Nevertheless, it should not be expected from a single employee to have all the competencies. Thus, each position will offer a different collection of competencies for Industry 4.0, such as creativity, and Critical Thinking, Cognitive Ability, Big Data Analytics and Interpretation, and Analytical Skills. Tables 1 to 8 present the competencies based on the SHL model categories.

Table 6
ORGANISING AND EXECUTING COMPETENCIES

Competency Dimension	Competencies
	Planning and Organizing Work
Planning and Organizing	Project Management
	Management Ability
Delivering Results and	Customer Orientation
Meeting Customer Expectations	Customer Relationship Management
Following Instructions and	Safety Awareness
Procedures	Legislation Awareness

Table 7
LEADING AND DECIDING COMPETENCIES

Competency Dimension	**Competencies**
Deciding and Initiating Action	Taking Responsibility
	Decision Making
Leading and Supervising	Leadership Skills

Table 8
ADAPTING AND COPING COMPETENCIES

Competency Dimension	Competencies
	Intercultural Competency
Adapting and	Work in Interdisciplinary Environments

Responding to Change	Flexibility
	Adaptability and Ability to Change Mind-set
Persuading and Influencing	Work-Life Balance

Table 9
CREATING AND CONCEPTUALIZATION COMPETENCIES

Competency Dimension	Competencies
Learning and Researching	Life-long Learning
	Knowledge Management
	Critical Thinking
Creating and Innovating	Innovating
	Change Management
	Creativity
	Business Strategy
Formulating Strategies and Concepts	Managing Complexity
	Abstraction Ability

Table 10
INTERACTION AND PRESENTING COMPETENCIES

Competency Dimension	Competencies
Relating and Networking	Compromising Maintaining Customer Relationships
	Creating Business Networks
Persuading and Influencing	Emotional Intelligence
Presenting and	Negotiating
Communicating Information	Presentation and Communication Ability

Table 11
ENTERPRISING AND PERFORMING COMPETENCIES

Competency Dimension	Competencies
Achieving Personal Work Goals and Objectives	Self-management and -organization
Entrepreneurial and Commercial Thinking	Business Model Understanding Entrepreneurship

Table 12
SUPPORTING AND COOPERATION COMPETENCIES

Competency Dimension	Competencies
Working with People	Communicating with People Teamwork Collaborating with Others
Adhering to Principles and	Environmental Awareness Respecting Ethics
Values	Awareness for Ergonomics

DISCUSSIONS AND CONCLUSIONS

Generally, this research study highlights the significance of employees' competencies to overcome the changes happening towards IR4.0 successfully. Findings from the literature review were mainly about behavioural competencies and a little about knowledge and technology competencies. The training of more competencies is still restricted to teamwork

situations or further discussions. The mentioned examples reveal that the focus in today's economy is on domain knowledge. At the same time, IR4.0 mostly affects work environments, and behavioral competencies are essential competencies for employees. Therefore, research must centre on studying exactly how today's and future employees' competency profiles can be conformed for IR4.0. This may include requirements' definition educational programs for IR4.0. We believe that this study will open the way for more research to be done on this topic. This study was based on a literature review. To enrich the results, further information can be collected through expert interviews and focus groups. Besides, further studies on IR 4.0 are needed to investigate other competencies and find a way to apply the model in practice, such as setting a competency profile for a specific job description.

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