Smart Manufacturing and Industry 4.0

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Industry 4.0 is an advanced strategy introduced by the German government to promote the integration of diverse technologies that make manufacturing process smarter. For instance, the technologies such as the Internet of Things (IoT), Internet of Service (IoS), social product development, Enterprise Resource Planning (ERP), and radio frequency identification (RFID) have been widely implemented to achieve smarter production system. The combination of this technology will foster mass customization, inexpensive product planning, accurate control of the manufacturing process, condition base maintenance, as well as the automated manufacturing process.
These technological trends are designed to facilitate machine to machine (M2M) communication using minimal to null dependence on human force. Industry 4.0 transform processes, operations, machinery, supply chain management, and the entire energy footprint of manufacturing enterprises. It also enhances and monitors the after-purchase performance such as maintenance and servicing. At the global front, manufacturing enterprises are already exploring the limitless possibilities of Industry 4.0 and are reimagining the future. The traditional manufacturing processes and machinery are undergoing digitization and technological transformation to accelerate efficiency, flexibility, and speed to survive the fierce market competition.

Keywords: Smart Manufacturing (SM) ; Industry 4.0 ; smart factory ; readiness assessment ; maturity model

1. Digitalization Transformation towards the Industrial Revolution

Digital technology is perceived as a mixed match of information, computing, communications, and connectivity technologies [1]. Digitalization will ensure that the manufacturing business runs efficiently, responsively, and cost-effectively [2]. In a holistic approach, digitalization is an enabler for a vertical (within the company) and horizontal (between companies) integration. Monostori et al. [3] and Nick et al. [4] reiterated that the vision of Industry 4.0 should have these four goals:

- *Vertical integration*: In a smart factory system, a digital model communicates via the cyber-physical system, which comprises people, machines, and resources, is mapped.
- *Horizontal integration:* The smart factory adapts itself to the surrounding system as it can optimize the entire production process in real-time.
- *Smart product:* The ability to retrieve product lifecycle information that will add to the digital modeling of the smart factory and offer a better product-based service.
- *Human Being:* The focal point and the driver of valued addition to the entire chain.

With the relationship between the service provider, supplier, and customer becoming integrated, a stand-alone automation manufacturing system is becoming an isolated choice [4]. Such a system has its limitation within the organization [5][2]. The disapproval of the stand-alone automation system is also due to the rising concern on interoperability between machines. The inability to communicate vertically and horizontally in Industry 4.0 offers the ideal answer for the misalignment between automation technologies. With the ability to interact with each other, the Cyber-Physical System (CPS) and the Internet of Things (IoT) are the missing puzzle pieces for the stand-alone automation solution [6]. Thus, integrating the philosophy of Industry 4.0 will help manufacturing businesses leap forward, and this involves strategical decisions due to the enormous investments that need to be made.

Many success stories have been attained from the significance of the digital transformation of an organization [1][7]. Digital technologies are viewed as a tool that profoundly eases the transformation of business strategies, processes, capabilities, the way their customers are served, and their product offerings. Digitalization is in line with Industry 4.0 [8][9]. Nevertheless, embracing digitalization is not an easy task and can become complicated at times. A survey done by the

Harvard Business Review [10] encompasses that corporate and people's culture, process, and technologies of the organization are directly influencing the transformation process. Henceforth, the manufacturing enterprises need to emphasize further the assimilation of inclusive knowledge and technology transfer [11].

2. Industry 4.0 Pillars in Crafting Smart Manufacturing (SM)

In line with Industry 4.0, Smart Manufacturing (SM) employs computer-integrated manufacturing, high levels of adaptability and rapid design changes, digital information technology, and more flexible technical workforce training [9]. Throughout the first industrial revolution to this date, other industrial revolutions have been driven by automation and digital transformation. Following the revolutions' trends, a smarter manufacturing system that is integrated with robots and sensors is expected to play a pivotal role in next-generation manufacturing.

With the birth of 5G technology, machines can interact, visualize the production chain, and make crucial decisions accurately and timely. Industry 4.0 is being backed by the combination of several new technology enablers as well as some existing technological apparatuses. Visibly, SM is a repackage of the combination of capabilities and technologies that serve as the pillar in making SM happen. The IoT, robotics, cloud computing, big data analytics, virtual reality, system integration, additive manufacturing, cyber security, and cyber-physical system are the pillars of the Industrial Revolution 4.0 [12][13][14][15][16][17].

3. Smart Manufacturing

Today's manufacturing is getting more complicated [18][19]. The term SM and Industry 4.0 expound the same reference meaning. In the United States of America, "smart manufacturing" is referred to as "Industry 4.0", and the Germans have officiated it in the Hannover Fair in the year 2011. Similarly, the Koreans refer to the term "Industry 4.0" as a "Smart Factory". Regardless of the terminology, these three terms signify the key goal of improving businesses and their manufacturing environments in diverse countries to connect and embrace the narrative of technological advancement in information and operation technologies. This noble aim is expected to facilitate steady income flows with the associated cost reduction and efficacy gains.

Lasi et al. [8] explained that to reduce operating costs, the prospect of future production is no longer dependent on batch order. This phenomenon has changed, and the manufacturer needs to think about smarter alternatives to meet customer-driven batch sizes while retaining mass production economies. As a driving force, intelligent sensors, intelligent solutions, innovative technologies, and the Internet and the Cloud are proven to promote digitalization and automation. Such disruptive developments of the technology enable product development time to be fostered and customization and versatility to be encouraged.

A smart factory consists of integrated systems from various components within a factory that makes the entire factory system more flexible and reconfigurable Wang et al. [20]. The smart factory system integrates and connects the industrial network via the cloud and supervisory control terminals with smart shop floor object that leads to autonomous decision making. This was primarily to develop smarter and higher-efficiency factory systems. Without cloud services, big data analysis, and networks, an intelligent self-organized multi-agent system cannot be established. Kang et al. [9] stressed that cutting-edge ICT technologies are enablers and drivers of manufacturing's fourth revolution. Wan et al. [21] and Zhong et al. [22] agree that a myriad of useful data is needed in making a smart factory. Davis et al. [23] explained that SM will lead and respond to dramatic and fundamental business transformations to demand dynamic economies with IT-enabled smart factories. Ultimately, Smart Factory focuses on the shift on task-connected changes focusing not only on profit but also on flexibility and product output, together with further declining cost, reducing resource utilization, as well as a decrease in ecological impact.

Despite the hype towards Industry 4.0, smart manufacturing, and the Smart Factory concept, Canetta, Barni, and Montini [24] have mentioned that numerous businesses have encountered challenges in implementing Industry 4.0. Rajnai and Kocsis [25] and Sony and Naik [5] indicated that some business owners are not clear on the current trend of industrial digitalization, and some leaders are clueless on how to implement it. Many manufacturing companies are still struggling to employ the SM concept [19][26][27][28]. With regards to the highlighted problems, readiness and maturity assessments have become an integral tool for the manufacturing enterprises, specifically for SMEs. A readiness model promotes the initialization of the development process. Since the business owner is uncertain about the consequence of Industry 4.0 technology [29], the readiness assessment is the right fit to diminish uncertainties on the invested technologies [30]. Readiness assessments are typically conducted on a self-assessment basis that can be performed online or offline. In this

self-assessment, the likely information gathered includes understanding, awareness, perception, current practice, as well as attitude of the organization.

To this date, many manufacturers are still exploring, working, and planning to boost their potentials so that they can stay relevant and face the market competition in time to come. In improving competitiveness, global manufacturing needs to empower themselves with technological breakthrough [9]. Rajnai and Kocsis [25] have commented that there is no rigid or standard model and commonly accepted methodology for measuring the adopters′ Industry 4.0 readiness. Some readiness assessments are found to only focus on organizational Infrastructure Technology (IT) readiness [31][32][33][34]. Furthermore, the assessment outcome is often measured using various dimensions. Shifting to a smarter way of manufacturing practice involves high investment and changes in the organization's vision-mission at the strategic level, as well as the modification of infrastructure and a new normal for the worker to adapt to. It does impact the Management, Machine, Method, and Man dimension in an organization. Choi, Jung, and Lee [35] have also reported that a maturity assessment could enhance manufacturing companies' competitiveness.

Since moving into Industry 4.0 is directly correlated to the amount of investment an organization must make, this is risky, as failure is costly for the SME's. Prior to the implementation of SM, it is crucial for SMEs to assess the readiness of their manufacturing company's practice [36][37]. For instance, most SMEs in Malaysia is still in the adopting stage of modern technology under Industry 3.0 [38]. The adoptions of the Industry 4.0 concept are still at the infancy level among the small and medium enterprises (SMEs) [39]. Herewith, this paper is constructed to propose a readiness assessment model to help SMEs stimulate their journey in their implementation of SM. Schumacher et al. [30], in their industry-wide interview, have spotted problems in implementing Industry 4.0 in a manufacturing business, as follows:

- Failure of assessing Industry 4.0 readiness and capability is costly.
- Failure to understand the uncertainty of the technology implementation will directly influence its benefits and cost.
- Lack of strategic assistance and prior knowledge of the Industry 4.0 concept will tarnish the organization's development.

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