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Assessing challenges for implementing Industry 4.0: Implications for process safety and environmental protection

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ABSTRACT

Researchers and practitioners are giving significant attention to Industry 4.0 due to its numerous benefits to manufacturing organizations. Several aspects of Industry 4.0 have been studied in the literature. However, studies on the challenges for implementing Industry 4.0 in manufacturing operations have received less attention. To address this gap, this study identifies a set of challenges (framework) for implementing Industry 4.0 in manufacturing industries. This framework is evaluated in the leather industry of Bangladesh aided by a novel multi-criteria decision-making method named Best-Worst method (BWM). The findings of the study showed that 'lack of technological infrastructure' is the most pressing challenge that may hurdle the implementation of Industry 4.0 whereas 'environmental side-effects' is the less among the challenges that may hinder implementation of Industry 4.0 in the Bangladeshi leather industry. This result may help decision makers, industrial managers and practitioners in the Bangladeshi leather industry to realize the actual challenges confronting them when attempting to implement Industry 4.0 and focus their attention on how to address these challenges to pave ways for a successful implementation of Industry 4.0.

1. Introduction

In today's competitive business environment, many business organizations are paying a significant attention to adopt smart technology in their production systems for improving the productivity, reducing risks and protecting the environment along with better quality products (Kolberg and Zühlke, 2015; Lu, 2017; Stock and Seliger, 2016; Varghese and Tandur, 2014). Hence, the concept of Industry 4.0 is becoming much popular among organizations due to its advantages in manufacturing processes as well as environmental protection. The development towards Industry 4.0 has greatly influenced manufacturing companies operations and decisions (Ford, 2015; Reinhard et al., 2016). The rapid development of information and communication technology (ICT) and internet of things (IoT) do facilitate the adoption of new technologies by manufacturing companies' to automate their manufacturing systems.

This development may impart immense opportunities for manufacturers to protect and control environmental impacts using smart technology, which can be developed via ICT and IoT (Lee et al., 2015; Reinhard et al., 2016; Schumacher et al., 2016). Yet, incorporating ICT and IoT based smart technology in manufacturing systems are not easily achieved by these companies due to some significant challenges (Chen et al., 2014; Lee and Lee, 2015; Qian and Wang, 2012). Therefore, it is requisite to identify and examine the challenges faced by these manufacturing companies when attempting to implement Industry 4.0.

Several researchers have conducted a number of studies on the initiatives to implementing Industry 4.0 but none have until now identified and examined the challenges confronted by organizations when attempting to implement Industry 4.0. This has warranted and motivated the need to carry out this research. For example, Waibel et al. (2017) investigated the effect of smart production systems in Industry 4.0 whereas Stock and Seliger, (2016) ascertained the opportunities of sustainable manufacturing in Industry 4.0. Faller and Feldmúller, (2015) in their study,

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investigated the learning factor of Industry 4.0 for regional Small and Medium Enterprises (SMEs). Lu, (2017) conducted a comprehensive review on Industry 4.0. These are some latest examples of studies conducted that are relevant to Industry 4.0 but clearly depicting the lack of studies on identifying and examining the challenges for Industry 4.0 implementation. To help fill this research gap, this study proposes a framework to investigate the challenges for implementing Industry 4.0 within the context of Bangladeshi leather industry. In this study, the challenges for implementing Industry 4.0 are assessed and ranked using a novel multi-criteria decision making (MCDM) tool named the 'best-worst method' (BWM).

The Bangladeshi leather industry was considered as the case industry due to several reasons. Firstly, the Bangladeshi leather industry is one of the most pollutant industrial sectors in the world (Hoque and Clarke, 2013). It is evident that the leather industry is largely responsible for the water, air and soil pollution as a result of their several chemical operations of raw hides and skins. Secondly, the Bangladeshi leather industry is one of the significant industrial sectors which contributes to Bangladesh foreign exchange with less amount of investment (Moktadir et al., 2017, 2018). Thirdly, the Bangladeshi leather industry is emergent and requires sustainable manufacturing practices such as smart manufacturing to help them make strategic decisions to minimize their environmental impacts thereby reshaping the industry's negative environmental reputations. Therefore, this research contributes to the state-of-the-art literature by addressing the following specific objectives:

(a) To identify the challenges for implementing Industry 4.0 in the Bangladeshi leather industry.
(b) To assess and rank these challenges using a novel multi criteria decision making based Best-Worst method.
(c) To suggest some practical and managerial implications of the study for implementing Industry 4.0.

To help address these objectives, the related literature is studied to identify some potential crucial challenges for implementing Industry 4.0 in the leather industry. To select the most crucial challenges, we conducted a series of brainstorming sessions with a group of industrial managers from the Bangladeshi leather industry. Then, evaluated and ranked the identified critical challenges using BWM. The reasons for selecting the BWM are provided as follows: i) it needs less number of pairwise comparison matrices which minimizes the evaluation time; and ii) the obtain results are more consistent compared to other MCDM tools (Marley, 2008; Rezaei, 2015a,b).

The reminder of the paper is structured as follows. In Section 2, the theoretical background of Industry 4.0, technologies used in Industry 4.0 and challenges to the implementation of Industry 4.0 are presented. Research methodology, composed of research design and the best-worst method are presented in Section 3. In Section 4, the application of the proposed challenges framework to a real world case problem in the Bangladeshi leather industry is provided, with results discussion and sensitivity analysis given in Section 5. Finally, conclusion, implications for process safety and environmental protection, practical implications and limitations of the study and recommendations for future research are highlighted in Section 6.

2. Theoretical background

2.1. Industry 4.0

The term 'Industry 4.0' refers to the fourth industrial revolution which is derived from the project related to computerized manufacturing of the future in the year 2011 (Vaidya et al., 2018; Tjahjono et al., 2017). This project was operated by German ministry of education and research. The applicability of the term 'Industry 4.0′ is popular in European countries especially in Germany's manufacturing sector (Gilchrist, 2016; Roblek et al., 2016; Rüßmann et al., 2015a,b). The term Industry 4.0 is based on the concept of Internet of services, Internet of Things, industrial internet and cyber physical systems, artificial intelligent (Davies, 2015; Lee et al., 2015; Rüßmann et al., 2015b). The basic characteristics of Industry 4.0 can be explained by four dimensions (Fig. 1): (1) vertical integration across the entire value chain and smart production system, (2) horizontal integration via new generation across the entire value chain networks, (3) Through-engineering across the entire product life cycle and (4) acceleration via smart technology (Deloitte, 2015).

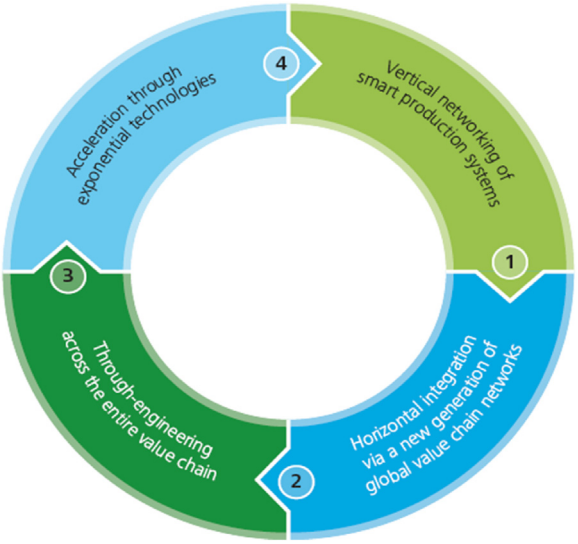

Fig. 1. The characteristics of Industry 4.0 (adopted from Deloitte 2015).

Vertical integration across the entire value chain and smart production system refers to the digitization and intelligent integration of the manufacturing plant via cyber physical production system and thus can create dynamic production system by considering rapid changes of demand and stock level (Ahuett-Garza and Kurfess, 2018; Wang et al., 2016; Zezulka et al., 2016). In this system, the resources and products are networked via vertical integration. Here, the smart sensor technology is used to monitor the whole system.

Horizontal integration via new generation across the entire value chain networks refers to the integration of intra- and inter-organizational intelligent and digitization throughout the value chain of a product life cycle (Erol et al., 2016; Ganzarain and Errasti, 2016). This system creates optimized networks that facilitate integrated transparency and offer high level of flexibility. Horizontal integration creates the dynamic production system across the entire process chain-from purchasing through production to sales.

The third Industry 4.0 characteristic, through-engineering across the entire product life cycle refers to the intelligent integration and digitization across the entire product life chain, that is, from the raw materials purchasing to end of the product life. In this stage, data may be available at all phases of product life cycle and facilitate the generation of more flexible production process (Gilchrist, 2016; Lasi et al., 2014).

The fourth important characteristic is acceleration via smart technology. The impact of smart technology in industrial production systems is so high. Smart technology can accelerate the entire production system by optimizing the production time, minimizing the production cost. Industry 4.0 requires introducing automa-

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