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Industry 4.0 Adoption in Manufacturing Industries Using Technology-Organization-Environment Framework

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ABSTRACT

This paper investigated the determinant factors affecting the Industry 4.0 ecosystem needed for the digitization and automation of manufacturing industries. The 4th industrial revolution implements a value chain by interfacing internet of things devices and robotics, data processing in the cloud using artificial intelligence-based analytics. The study was conducted in Pune, India, a manufacturing and IT services hub. It sought to identify Industry 4.0 facilitators and inhibitors by framing empirical data collected from 320 manufacturing facilities and analyzed using PLS-SEM within a model based on technology-organization-environment (TOE) theory and motivation-threat-ability (MTA) theory. The results confirmed that technology competence, organization scope, consumer readiness, competitive pressure, trading partners' readiness, and governance practices are the facilitators, whereas organization resistance inhibits Industry 4.0 adoption intentions. The outcome of this study shall provide guidelines to manufacturing industries management as well as technology solution providers.

KEYWORDS

Industry 4.0, Manufacturing Industries, Motivation-Threat-Ability Theory, PLS-SEMTechnology-Organization-Environment Theory

1. INTRODUCTION

Manufacturing industry contribution to the national economic system and society is significant. India will be the fifth largest manufacturing country in the world by 2020 (McKinsey and Company, 2015). The Indian manufacturing industry is forecasted to contribute 25% to Gross Domestic Product (GDP) contributing US$ 1 trillion by 2025 (India Brand Equity Foundation, 2017). To boost up manufacturing industry, Government of India initiative "Make in India," and the 'National Policy for Advanced Manufacturing' is enabling Industry 4.0(I4.0) adoption. These are cyber-physical systems(CPS) optimizing manufacturing through the connected value chain, driven by the internet of things (IoT), big data, high computing capacity, cloud, artificial intelligence, 3D printing, inspection drones, and analytics. Industrial IoT (IIoT) has enabled complete digitization and automation of manufacturing processes leading to the 4th industrial revolution (Chi et al., 2014; Xu, He & Li, 2014). I4.0 term was introduced by the German Government, 'German National Academy of Science and Engineering' as part of the "High-Tech Strategy 2020" in 2010 ensuring competitiveness for the manufacturing industry (Kagermann et al., 2015). IoT technology allocates Digital Object Identifier to each object

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(Gershenfeld et al., 2004), creating a network (Kortuem et al., 2010) to exchange products, services, and information (Chen et al., 2011). Manufacturing industries are dedicated, standardized production environments enabling process improvements through I4.0. McKinsey Global Institute stated that I4.0 benefits are operations optimization, predictive maintenance, inventory optimization, human productivity (monitoring), logistics, and pre-sales analytics. It will expand marketing opportunity by improving products/services and provide competitive advantage (Teece, 2010).

India's progress in IoT and big data, is developing 'smart factories' leading to mass customization. I4.0 is directing towards the globalization, rapid material transfer, cashless payment, and smaller products' life cycles fulfilling customers' needs (Shepherd and Ahmed, 2000) and developing products and services to meet customers' demands (Peteraf, 1993; Porter, 1990).

Low robot density and I4.0 patents need higher R& D investment to establish smart factories, (Kagermann et al.,2015) giving rise to disruptive business models (Bauernhansl et al., 2014). IT knowledge and infrastructure should be leveraged (Pramanik, 2019) with a shift in the mindset, capital expenditure, policy implementation, and skilled labor. As per the World Economic Forum (WEF) in 2016, India was ranked 91st out of 139 countries in the Network Readiness Index as only 10-20 percent of manufacturing industries were undertaking digitization activities. Reluctance towards technology investments was because of the short-sighted management, small scales, and margins. Most of the Indian manufacturing industries are low value and high volume, utilizing low skilled labor. The role of I4.0 integrating cyber-physical systems is still in an emerging stage (Xia et al., 2012) as the ecosystem for I4.0 adoption is not developed (Miorandi et al., 2012). Efforts to create a collaborative and innovative ecosystem made by the Government have to be partnered by Industry and Academia.

Previous studies focused on managing I4.0 technology concepts (Dohale and Kumar, 2018) however empirical research and case studies are required to increase the I4.0 adoption (Kamble et al., 2018; Da Xu et al., 2014; Gubbi et al., 2013). This gap is addressed by exploring the key factors that are enablers and disablers for the adoption of I4.0 in manufacturing industries.

RQ1: What are the overall factors which impact Industry 4.0 adoption by manufacturing industries in India?

2. LITERATURE REVIEW

2.1. Industry 4.0

Manufacturing industries those implemented mainframes, Client-server architecture in the past are now shifting to the cloud, mobility, big data analytics, and social business (IDC Manufacturing Insights, 2015). Easy availability and the increasing power of sensors and actuators make IoT use ubiquitous in industrial applications (Kranenburg, 2008). Industry 4.0 is the convergence of nine disruptive technologies autonomous robots, big data, augmented reality (AR), additive manufacturing, cloud computing, cybersecurity, IoT, system integration, and simulation. I4.0 refers to the value chain organization that connects cyber-physical systems, capable of sensing, identification, processing, communication, and networking.

2.2. Underpinning Theory

Industry 4.0 is adopted by an organization; hence, in this study unit of analysis had to be an organization level. Detailed insights obtained from previous studies and industry users highlighted that I4.0 adoptions by manufacturing industries depended on entire organization ecosystem consisting of technology competence, organization scope, environmental forces, and organization resistance (Siemieniuch and Sinclair, 2015). Quantitative research is based on the theoretical foundation to develop hypotheses; therefore, this study adopts the TOE and MTA theoretical framework.