Educational Administration: Theory and Practice
2024, 30(1), 5460 - 5464
ISSN:2148-2403
https://kuey.net/

Research Article

Embracing Industry 4.0: Pathways and Implications for Micro, Small, and Medium Enterprises (MSMEs) in India

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Citation: Dr. Vinay Pal Singh et al. (2024), Embracing Industry 4.0: Pathways and Implications for Micro, Small, and Medium Enterprises (MSMEs) in India, *Educational Administration: Theory and Practice*, *30*(1), 5460 - 5464
Doi: 10.53555/kuey.v30i1.9031

ARTICLE INFO

ABSTRACT

MSMEs significantly contribute to GDP and employment; however, they face challenges such as limited access to technology and financial resources, which affect their competitiveness on a global scale. Through a comprehensive literature review, this study underscores the pivotal role of digital technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and Cyber-Physical Systems (CPS), in transforming MSME operations. It explores the benefits of technology adoption, such as enhanced productivity, efficiency, and market reach. Furthermore, the paper identifies major barriers to technology integration and proposes strategies to surmount these obstacles, thus promoting a more resilient and competitive MSME sector in India. The findings indicate that while the journey towards digital transformation is filled with challenges, strategic government support and customized technological solutions could empower MSMEs to excel in the digital economy.

Keywords: MSMEs, Industry 4.0, Technology Adoption, Economic Growth, Digital Transformation, IoT, AI, India.

Introduction

In India, the classification of Micro, Small, and Medium Enterprises (MSMEs) is determined by a composite criterion involving both investment and annual turnover. This revised definition, applicable from July 1, 2020, stipulates that (Ministry of MSME , 2024).
- *Micro Enterprises:* are those where the investment in plant and machinery or equipment does not exceed Rs. 1 crore, and the annual turnover does not surpass Rs. 5 crore.
- *Small Enterprises:* involve an investment of not more than Rs. 10 crore and an annual turnover that does not exceed Rs. 50 crore.
- *Medium Enterprises:* are defined by an investment limit of not more than Rs. 50 crore and an annual turnover of less than Rs. 250 crore.

The Government of India has excluded export turnover from these limits to encourage MSMEs to participate more actively in the global market without losing domestic benefits (Ministry of MSME , 2024).
Micro, Small, and Medium Enterprises (MSMEs) make significant contributions to the Indian economy. MSMEs contribute notably to India's Gross, MSME Gross Value Added (GVA) has accounted for about 30% of India's total GDP. This figure reflects the sector's vital role in the national economy, consistently contributing around 30-30.5% over the years (PIB, 2023)MSMEs are a major employment generator in India. As of recent counts, there are over 15.5 crore people employed in the sector. This large workforce underlines the sector's role as a cornerstone for job creation, particularly important in a country with a vast and diverse population (PIB, 2023). The export contribution of MSMEs is also significant, with MSME-related products comprising about 45-50% of total Indian exports in recent years. This highlights the sector's crucial role in India's international trade dynamics (PIB, 2023).
The MSME sector in India is a crucial driver of economic growth, contributing significantly to industrial production, GDP, and employment (Ministry of MSME , 2024). This sector is characterized by low investment and technology requirements, operational flexibility, and import substitution (Manohar 2018, Ramesha M 2021). However, it faces challenges such as lack of access to finance, technology, and skilled labor, as well as regulatory and infrastructure constraints (Rani 2014, Ramesha M 2021).

A range of studies have explored the relationship between technology adoption and firm performance. Chen (2006), Bartelsman (1995) both found positive effects, with IT adoption leading to service innovation and improved performance, and the adoption of advanced manufacturing technology (AMT) correlating with higher productivity and employment growth. Arifin (2015) and Stoneman (1996) identified key factors influencing technology adoption, such as externalities, leadership, and absorptive capability, and the impact of technology adoption on profitability. Shin (2006) and Alonso-Almeida (2013) focused on specific technologies, with the adoption of enterprise application software (EA) and information and communication technologies (ICTs) both leading to improved productivity and competitiveness. Majumdar (1995) further supported these findings, showing that the adoption of electronic switching technology in the US telecommunications industry led to superior resource utilization and performance.

Technology adoption is also an important driver of firm sustainability. Past research has shown that the adoption of sustainable technologies is crucial for addressing environmental challenges and achieving sustainable development (Dunmade (2013), Tiwari (2020) Durge (2015) and Olawoyin (2020) Tonn (2008) and Khanna (1999) Yacob (2017) and Huang (2021).
Thus, on the basis of the above discussion, the current papers reviews the literature on how industry 4.0 adoption is beneficial for the Indian MSMEs.

Literature Review

Research on technology adoption in MSMEs in India has highlighted several key factors. Singh (2013) and Jain (2011) both emphasize the importance of technology in enhancing competitiveness and growth, with Singh (2013) specifically noting the benefits of advanced manufacturing technologies and Jain focusing on the potential of mobile commerce. Gupta (2022) and Das (2012) both explore the role of financial technology and information technology in MSMEs, with Gupta finding a high acceptance rate of financial technology and Das identifying information exchange with customers and government incentive schemes as key influencers of IT adoption. Shetty (2020) further discusses the potential of the Digital India program in supporting cloud adoption. These studies collectively underscore the potential of technology in driving growth and competitiveness in Indian MSMEs.

The adoption of technology, including information technology (IT) and advanced manufacturing technologies (AMT), is crucial for the growth and competitiveness of Micro, Small, and Medium Enterprises (MSMEs) in India (Singh 2013, 2015). This adoption can lead to quality improvements, cost reductions, and increased sales (Singh 2013). Financial technology, in particular, plays a significant role in the financial inclusion of MSMEs, with factors such as prior experience, brand familiarity, and government support influencing its adoption (Gupta 2022). However, MSMEs face various challenges in technology adoption, including limited knowledge, ineffective marketing strategies, and constraints on modernization (Das 2012, Srivastava 2013). The adoption of information and communication technology (ICT) can also improve the performance of MSMEs, with factors such as relative advantage, compatibility, and management support influencing its adoption (Ali 2023). The MSME sector in India, a key driver of economic development, faces various challenges including technological obsolescence, supply chain inefficiencies, and increasing competition (Baral, 2013). To address these challenges, the sector needs to adopt innovative approaches and modern manufacturing technologies (Chakrabarty, 2020; B.Chaudhary, 2018). The Fourth Industrial Revolution (4IR) presents both opportunities and challenges for MSMEs, necessitating policy reforms and technology adoption (Chakrabarty, 2020). The sector's role in employment generation, industrialization, and wealth distribution is significant (Katyal, 2015; Unnisa, 2015; Pujari, 2021).
Industry 4.0, also known as the Fourth Industrial Revolution, refers to the integration of advanced digital technologies into manufacturing and industrial processes, resulting in the creation of "smart factories" and transformative changes in production systems. Scholarship has defined Industry 4.0 as follows:
Industry 4.0 is described as "a fusion of advances in artificial intelligence (AI), robotics, the Internet of Things (IoT), cloud computing, and other digital technologies to create smart factories and intelligent manufacturing systems" (Schwab, 2016). Industry 4.0 represents "the convergence of digital and physical technologies, such as IoT, cyber-physical systems, cloud computing, and cognitive computing, to create value-added, smart and adaptive manufacturing processes" (Lee et al., 2015).
Industry 4.0 is characterized by "the digitization and networking of products, value chains, and business models, enabling real-time data collection, analysis, and decision-making to optimize production processes and enhance productivity" (Porter & Heppelmann, 2014).
Industry 4.0 encompasses "the use of digital technologies to enable the integration of information, communication, and automation technologies in manufacturing processes, leading to increased flexibility, efficiency, and customization" (Weyer et al., 2015).
Industry 4.0 encompasses a wide range of new technologies under its umbrella, the chief technologies used are as follows:
Internet of Things (IoT): IoT refers to the network of interconnected devices and sensors that collect and exchange data in real-time. In Industry 4.0, IoT enables the creation of smart factories by facilitating the

monitoring and control of machinery and processes. For example, "IoT enables real-time monitoring of machine conditions and predictive maintenance, leading to improved asset utilization and reduced downtime" (Rajput & Yagnik, 2020).

Artificial Intelligence (AI): AI technologies, including machine learning and deep learning, play a crucial role in Industry 4.0 by enabling machines to learn from data, make decisions, and perform tasks autonomously. AI enhances manufacturing processes by optimizing production, quality control, and supply chain management. For instance, "AI algorithms analyze manufacturing data to identify patterns and anomalies, enabling predictive maintenance and quality optimization" (Wang & Zhang, 2021).

Cyber-Physical Systems (CPS): CPS integrate physical components with computational and communication systems, enabling seamless interaction between the physical and digital worlds. In Industry 4.0, CPS enable real-time monitoring and control of manufacturing processes, leading to increased efficiency and flexibility. For example, "CPS enable the synchronization of production processes and supply chain activities, improving responsiveness and agility" (Lee et al., 2015).

Robotics and Automation: Robotics and automation technologies enhance productivity and efficiency in Industry 4.0 by automating repetitive tasks and enabling human-robot collaboration. Advanced robotics systems, including collaborative robots (cobots), enhance manufacturing flexibility and enable agile production. For instance, "Robotic systems equipped with AI and IoT capabilities enable autonomous material handling and assembly tasks in smart factories" (Arun & Ganesan, 2021).

Integrating Industry 4.0 with Traditional Industries – A Scope for MSMEs in India

Integration of AI and IoT: Recent research focuses on the integration of artificial intelligence (AI) and the Internet of Things (IoT) to enhance the capabilities of Industry 4.0 systems. For example, "Recent studies explore the integration of AI algorithms with IoT sensors for predictive maintenance and quality optimization in smart manufacturing" (Papakostas et al., 2020).

Cybersecurity in Industry 4.0: With the increasing connectivity of industrial systems, there is a growing focus on cybersecurity issues in Industry 4.0. Researchers are investigating strategies to enhance cybersecurity measures and protect critical infrastructure from cyber threats. For instance, "Recent studies propose advanced cryptographic techniques and intrusion detection systems to safeguard industrial networks and data in the Industry 4.0 era" (Alcaraz et al., 2021).

Human Factors and Human-Machine Interaction: There is a growing recognition of the importance of human factors and human-machine interaction in Industry 4.0 research. Recent studies explore how to design user-friendly interfaces and collaborative work environments that facilitate human-robot interaction and cooperation. For example, "Recent research emphasizes the design of intuitive user interfaces and adaptive automation systems to enhance human-robot collaboration in smart manufacturing environments" (Abu Qudeiri et al., 2020).

Sustainable Manufacturing and Circular Economy: Research on Industry 4.0 increasingly focuses on promoting sustainability and circular economy principles in manufacturing processes. Recent studies explore how digital technologies can be leveraged to optimize resource utilization, reduce waste, and enhance environmental performance. For instance, Bocken et al., (2020) investigates the application of Industry 4.0 technologies such as IoT and AI to enable closed-loop production systems and sustainable manufacturing practices.

Technology Adoption Mechanisms

A range of technology adoption models have been developed, with some integrating multiple theories (Ogrezeanu, 2015; Al-Tarawneh, 2019; Dube, 2020). These models have been applied to various fields, including information technology (Schwarz, 2013; Sahouly, 2015; Olushola, 2017), business organizations (Dube, 2020), and the agricultural sector (Dissanayake, 2022). The Technology Acceptance Model (TAM) is a widely used model in these studies, often in combination with the Theory of Planned Behavior (TPB) (Al-Tarawneh, 2019; Olushola, 2017). However, there is a need for further research to explore the contextual factors influencing technology adoption and to develop more comprehensive models (Ogrezeanu, 2015; Dube, 2020; Dissanayake, 2022).

The adoption of Industry 4.0 technologies varies across industries and is influenced by a range of factors. Early adopters tend to be larger firms with greater technological readiness and a perception of relative advantage (Lee, 2022; Junior, 2022). The adoption process is influenced by a range of factors, including cost-benefit considerations, management support, workforce competence, and environmental factors (Ariyani, 2021). The challenges of adoption include market uncertainty, competitive advantage, and top management support (Prause, 2019). Despite the potential benefits, smaller firms with limited financial resources may be less likely to adopt these technologies (Mayol, 2020). The transformative potential of Industry 4.0 technologies in performance management is also highlighted, with the potential to enhance objectivity and efficiency (Pawar, 2023). However, there are still limitations to full adoption, including the need for increased integration of digital technologies and smart manufacturing methods (Das, 2022).

Conclusion

India has over 48 million MSMEs contributing substantially to our country's industrial output, exports, and employment (Govt of India, 2023). Therefore, it is imperative for these businesses to embrace digital transformation to remain competitive in today's globalized market (Masood and Sonntag, 2020). The main challenges towards industry 4.0 adoption by MSMEs are to identify their applications in their processes and to measure the business results of the industry 4.0 solutions (Rupp et al., 2021). Masood and Sonntag (2020) report that SMEs show an inclination to implement Industry 4.0 technologies but factors such as financial and knowledge constraints are found to be key challenges. Thus, it is essential to study the adoption process of industry 4.0 tools by MSMEs and its effect on outcomes such as competitive advantage and firm performance. In addition, he the available research reports that implementation of industry 4.0 is mainly studied for larger organisations or multi-national enterprises such as Sheel and Nath (2020) have studied the adoption of Block chain Technology by large scale Indian firms (turn over exceeding 50 million INR).

Although MNEs contribute significantly to the economy, it cannot be ignored that MSMEs make up significant contribution (33%) to India's GDP and thus, it is essential to study their adoption of industry 4.0 . Sheel and Nath (2019) have highlighted that use of Industry 4.0 technologies (such as Block chain) by firms helps in yielding a superior competitive advantage. Therefore, we also posit that adoption of industry 4.0 by MSMEs will lead to better competitive advantage for them. In addition, Sheel and Nath (2019) have highlighted that use of Industry 4.0 technologies (such as Block chain) by firms helps in improving their firm performance. Therefore, we also posit that adoption of industry 4.0 by MSMEs will lead to better firm performance of MSMEs.

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