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Research Article

Application and Effect of Industry 4.0 and Cloud Technology in MSME Using Case study

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Abstract: Implementation of Industry 4.0 and cloud technology demands heavy financial allocation for its infrastructure and its integration. It's important to calculate advantages related to implementation of new technologies. Operational efficiency of the MSMEs improved by implementing cloud technology and Industry 4.0. Literature review conducted on operational efficiency, MSME and some factors which enablers, industry 4.0 and cloud technology. For the study purpose, there were three MSMEs have been considered in India, where first MSMEs (X company) have implemented cloud technology, the second company (Y company) with cloud technology and Industry 4.0. Whereas third MSME (Z company) has not implemented any new technology other than ancient conventional equipment. Few aspects are also considered and compared for the detailed discussion. By real time implementation of new technology helps MSME to improve operational efficiency. All three Companies (X, Y and Z company) are compared and concluded that operational efficiency of X company and Y company is increased to desirable percentage and that may encourage third MSME (Z company) to implement new technology. And this suggest that implementing new technology will improve the overall performance of the MSME.

Keywords: Industry 4.0, Cloud Technology, MSME, Operational Efficiency

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INTRODUCTION

The implementation of Industry 4.0 and cloud-based technologies necessitates substantial financial investment in both infrastructure development and system integration. Consequently, it is imperative to undertake a rigorous evaluation of the potential advantages associated with the deployment of such advanced technologies. Scholarly analyses of Industry 4.0 adoption within micro, small, and medium enterprises (MSMEs) frequently employ diverse case study approaches to assess its feasibility. Notably, these investigations reveal that the discourse surrounding implementation is predominantly framed in terms of cost considerations, underscoring the financial dimension as the central determinant of adoption strategies.

Industry 4.0 signifies the advancement of digital transformation through the integration of machines, production systems, logistics networks, and human operators, facilitated by sensors and control technologies. This interconnected infrastructure fosters the emergence of smart factories, intelligent manufacturing processes, and adaptive value chains. For small and medium-sized enterprises (SMEs), the strategic adoption of Industry 4.0 tools enhances organizational agility, adaptability, and resilience, enabling them to navigate competitive markets more effectively. By positioning themselves as innovative and responsive collaborators, SMEs can strengthen their role within the power dynamics traditionally dominated by larger buyer organizations [1]. For the study purpose, there were three MSMEs have been considered in India.

In this study, three categories of micro, small, and medium enterprises (MSMEs) are examined to evaluate the impact of technological integration on performance efficiency. The first enterprise has adopted both Industry 4.0 and cloud technologies, thereby embedding advanced digital infrastructure into its operations. The second enterprise has implemented cloud technology alone, without the broader framework of Industry 4.0. The third enterprise, by contrast, operates without the incorporation of modern technologies. This third case is deliberately included in the analysis to serve as a baseline, enabling comparative assessment of performance outcomes against the technologically enabled enterprises.

The scholarly discourse on small organizations has devoted limited attention to their operational efficiency. The significance of this research lies in its examination of how the implementation of advanced technologies—specifically cloud computing and Industry 4.0 frameworks—can yield measurable improvements in the efficiency of micro, small, and medium enterprises (MSMEs). In addition to evaluating performance outcomes, the study also addresses the financial implications associated with technological adoption. The findings serve to encourage MSMEs to embrace such innovations, highlighting the potential for enhanced performance and the broader benefits that accompany digital transformation.

This paper employs both qualitative and empirical approaches to examine the dynamics of technological adoption. The empirical component specifically addresses the post-implementation phase of new technologies, thereby providing insights into their practical impact. The integration of Industry 4.0 and cloud-based solutions represents an emerging domain within the Indian manufacturing sector, underscoring the novelty and relevance of this investigation.

Literature Review

Industry 4.0 encompasses a suite of advanced technologies—including the Internet of Things (IoT), the Industrial Internet of Things (IIoT), sensors, additive manufacturing (3D printing), automation, and big data analytics—designed to integrate and optimize business processes within manufacturing environments. Its structural framework is defined by three dimensions of integration: horizontal integration across value networks, end-to-end engineering throughout the product lifecycle, and vertical integration linking plant operations, manufacturing activities, and enterprise resource planning (ERP) systems. Collectively, these dimensions establish a cyber-physical system that characterizes the fourth industrial revolution. Historically, Industry 1.0 was marked by mechanization through steam and water power; Industry 2.0 introduced electricity and mass production; Industry 3.0 advanced electronics and the automation of IT systems; and Industry 4.0 extends these revolutions by embedding digital connectivity and intelligent systems into manufacturing processes [2].

From the knowledge of available processes, Core of the Industry 4.0 is capable to predict the manufacturing outcomes. Simplification of Industry 4.0 is a system creation to extend the use of knowledge domain [3]. From available IT and industrial automation, industry 4.0 increases manufacturing systems' flexibility and scalability. Many governments encourage industries, to shift to industry 4.0 with controversial success. Funding action makes many industries even small firms to implement industry 4.0. IoT makes all available processes into single smart factory network. Optimized IT oriented processes and Industrie 4.0, create a better tracking system of processes by recording which were never recordable [4].

A smart manufacturing system integrates advanced information technology services into existing production frameworks to accelerate productivity, enhance product efficiency, and optimize profitability. Such systems are inherently flexible, permitting modifications or updates to products at any stage of the manufacturing process. This adaptability exemplifies the principles of agile manufacturing, wherein responsiveness to change is embedded as a core operational capability [5].

The successful implementation of Industry 4.0 within micro, small, and medium enterprises (MSMEs) is contingent upon three critical factors: awareness, capability, and willingness. However, many MSMEs lack adequate awareness of the technological landscape, while their capacity to incorporate such innovations remains constrained by limited resources and expertise. Furthermore, the willingness to allocate investments toward implementation is minimal, thereby impeding the broader diffusion of Industry 4.0 practices across the sector [6].

Roadmap to carry out industry 4.0 is not clear in both industry and academia [7]. The tangible realization of Industry 4.0's advantages requires transitioning from conceptual frameworks to practical implementation. To facilitate the adoption of Industry 4.0 and cloud technologies within micro, small, and medium enterprises (MSMEs), targeted government funding is essential to mitigate financial barriers. Strengthening data security standards is equally critical to ensure trust and sustainability in digital operations. Furthermore, structured training and development programs for internal employees are necessary to enhance technological competence and enable MSMEs to effectively adapt to ongoing advancements in manufacturing innovation.

In cloud based concepts, real data has become virtual data and those data are continuously moving throughout the cloud. So security issues may arise in both storage of data and handling of data. To strengthen the security of data in manufacturing environment, the data has to be stored locally in organization level server, and then these data can be synchronized with cloud database [8].

Most of the studies on Industry 4.0, consider only one factor and focused on technological side [9].

This study offers critical guidance for decision-makers in designing a coherent and effective strategy for the adoption of digital technologies. It must be acknowledged that the foremost priority of small enterprises is not the advancement of e-business initiatives, but rather the imperative of survival within volatile market environments and the preservation of their customer base. In contrast to larger corporations, smaller firms often refrain from proactive strategic actions and frequently neglect digitization practices. Digitization, defined as the transformation of physical information into digital formats, remains underutilized in such contexts. Furthermore, the confidence of small enterprises in matters of data protection and cyber security is generally limited, thereby constraining their capacity to pursue comprehensive digital transformation [10].

MSME

Empowering micro, small, and medium enterprises (MSMEs) in the digital era is indispensable, as it constitutes a strategic investment in economic development, technological innovation, and sustainable livelihoods. Ultimately, the pursuit of a digitally inclusive and prosperous future for MSMEs commences with the systematic cultivation of workforce competencies [11].

Within the context of micro, small, and medium enterprises (MSMEs), the availability of financial resources, the adoption of advanced technologies, adherence to standardized practices, collaboration with universities, and the establishment of robust organizational structures remain comparatively limited. Conversely, MSMEs exhibit strong product specialization and a pronounced reliance on collaborative associations, which serve as critical mechanisms for sustaining competitiveness and innovation despite structural constraints [12].

Industry 4.0 Technologies

- Internet of things (IoT)
- Smart factories
- Internet of services
- Cyber physical system
- Sensors
- Additive Manufacturing [13]

Internet of Things

The Internet of Things (IoT) refers to the interconnected network of physical objects and devices that communicate and collaborate to achieve predefined objectives. Core components such as sensors and actuators exemplify this paradigm, enabling real-time data collection and responsive actions. By seamlessly merging physical elements with digital systems, IoT facilitates the creation of more intelligent and efficient products, thereby enhancing functionality and value in diverse applications [14]. The data is collected from the sensors and processed in cyberspace and correction is taken in real-time to change the real world [15].

Operational Efficiency

Micro, small, and medium enterprises (MSMEs) constitute a fundamental pillar of national economies, making substantial contributions to economic growth, employment generation, and the improvement of societal welfare. Despite their pivotal role, MSMEs continue to encounter persistent challenges, particularly in relation to limited human capital, financial constraints, and inadequate infrastructure. In light of these obstacles, the present study seeks to critically analyze the extent to which technological innovation can serve as a catalyst for enhancing the operational efficiency of MSMEs, thereby strengthening their competitiveness and sustainability within an evolving economic landscape [16]. The operational efficiency of manufacturing enterprises is often undermined by inadequate communication across departments. Achieving optimal efficiency necessitates the establishment of effective channels of communication and sustained cooperation among all functional units involved in the production process. Such integrative collaboration ensures that organizational objectives are met with greater precision and consistency [17]. "Manufacturing is a force multiplier; it means investment in manufacturing yields four times the effect on gross domestic product (GDP) growth" [18]. Table 1 shows Cloud technology and Industry 4.0 implementation in MSME.

Table 1: Cloud Technology and Industry 4.0 Implementation in MSME

S.NO	NATURE OF STUDY	METHODOLOGY ADOPTED	AUTHORS
1	Improve education and companies' training and research field of industrial engineering and logistics	Case study using learning factory- Lean lab	Karre <i>et al.</i> [19]
2	Improve future production technology using problem oriented environment for	Case study using learning factory- Tentative competency model	Erol <i>et al.</i> [20]
3	Improving technical aspects using lean methods comprising socio technical aspects	Literature review	Davies <i>et al.</i> [21]
4	To improve training and learning methods, incorporating collaborative engineering in Product life cycle framework	Using software applications of Industry 4.0	Vila <i>et al.</i> [22]
5	Increasing productivity and competitiveness	Collaboration mechanism	Schuh <i>et al.</i> [23]
6	Improving utilization of Industry 4.0 associated with size of organization	Quantitative study has been conducted	Sommer, [24]
7	Improving external reliability	Self- explanatory method case study	Suresh N <i>et al.</i> [6]
8	Integrating business system and processes involved to get optimum and effective operation	Case study	Qin <i>et al.</i> [7]
9	Extensive technology push to mechanization, digitalization and networking and application pull to shorten development period, to increase flexibility and resource efficiency	Conceptual paper	Lasi <i>et al.</i> [25]

Case studies

There three types case studies the company names are kept confidential and mentioned X, Y and Z

Company X

Company X, situated in Bangalore, India, operates as a micro, small, and medium enterprise (MSME) specializing in design and manufacturing. The organization has adopted SAP, which underpins its digital infrastructure and facilitates seamless integration of processes. Owing to this robust infrastructure, the implementation of Industry 4.0 concepts across multiple operations is relatively straightforward. The enterprise employs advanced manufacturing equipment, including CNC milling machines and molding machines, to produce mechanical components.

The entire system functions within a cloud-based environment, wherein critical data—such as inventory, procurement, and supply chain information—is stored and managed. This cloud architecture enables real-time retrieval, processing, and utilization of data to support predictive analytics, including product lifetime estimation and monitoring of wear in automated machinery. Consequently, the infrastructure ensures continuous tracking and analysis of operational data, thereby enhancing efficiency, reliability, and decision-making in manufacturing processes.

The integration of network connectivity and specialized software enables predictive analysis of resource utilization and facilitates the coordination of operational processes. The existing infrastructure provides substantial scope and potential for the adoption of emerging technologies. The implementation of cloud technology and Industry 4.0 practices has been achieved with strong employee support, largely due to their inherent flexibility and practical utility. Employee training programs were conducted over a brief period, yet proved sufficient for effective adaptation.

Cloud technology enhances both the speed and accessibility of data management. Data security is safeguarded through firewall protection and two-factor authentication, overseen by a small IT department. Distributed production units are interconnected via advanced networking systems, ensuring seamless communication and integration. The effective deployment of these technologies contributes significantly to improved system quality and operational efficiency.

Company Y

Company Y, an MSME located in Gujarat, India, operates in the domain of design and manufacturing. The enterprise employs approximately 250 personnel and reports an annual turnover below ₹250 crore. Its primary product line consists of plastic pipes manufactured in both metric and imperial dimensions. Production activities are supported by advanced equipment, including CNC machines and boring machines, which facilitate precision manufacturing.

The organization has adopted SAP to streamline production processes and maintain inventory with high accuracy. This digital infrastructure provides a robust foundation for the integration of Internet of Things (IoT) technologies, thereby enhancing operational efficiency. The adoption of IoT has significantly reduced manufacturing cycle times, with per-piece production time decreasing 35 seconds from minute. As a result, the company has achieved measurable improvements in productivity and overall system efficiency.

Table 2: Comparing aspects of Company X, Company Y and Company Z

S.No	comparison point	First company (X)	Second Company (Y)	Third company (Z)
1	Nature of the firm	Design and Manufacturing	Design and Manufacturing	Design and Manufacturing
2	Method of information management	ERP, Cloud	ERP, Cloud	Manual
3	System cost	High	High	Low
4	Flexibility	High	High	Low
5	Data security	Cyber Threat	Cyber Threat	High
6	Adaptability of employees for compatibility	Low	Low	High
7	Organizational productivity	High	High	Low
8	Level of Integration with inter- departments (Shop floor, Purchase, Marketing and sales and Human resource	High	High	Low
9	Efforts required to shift the current system to new technology	Low	Low	Very high
10	Inventory management	ERP, Cloud	ERP, cloud	Manual

A firewall has been installed to safeguard organizational data, which is stored on centralized servers. Employee training programs are conducted to enhance workforce efficiency and adaptability to new technologies. Sensors play a pivotal role in capturing measurements by identifying the appropriate time and location. Parameters such as temperature, time, and shape are monitored through sensor positioning, with measurement instructions—what to measure, where, and when—integrated into the software system.

Multiple sensor types, including proximity, positioning, and thermal sensors, are deployed alongside pressure gauges and actuators to strengthen monitoring capabilities. The integration of sensors with internet connectivity enables data to be stored online, ensuring accessibility via mobile devices and traceability from any location. The adoption of these technologies has significantly improved process capability. As highlighted in earlier sections, enhanced worker efficiency directly contributes to increased organizational productivity.

Table 2 shows the details of three Firms Company X company Y and company Z.

Company Z

Company Z, a micro-scale enterprise located in Maharashtra, India, specializes in design and fabrication of metal products. The firm employs fewer than ten individuals and records an annual turnover below ₹5 crore, with its customer base concentrated primarily within Maharashtra. Manufacturing operations are supported by a range of machines, while inventory and production planning are managed through shared Excel files, updated collaboratively by multiple employees. Although certain technical software is utilized, the company lacks a dedicated information system to integrate and streamline operations.

As Company Z engages with larger firms, it faces external pressure to adopt cloud-based technologies. However, management expresses reservations regarding such implementation. The perceived challenges include:

- The new technology and system is expensive
- Owner of the company feels that training programs and for employees need more cost
- Data security is less if new system and internet is involved
- The benefit of industry 4.0 and cloud technology implementation are doubtful for the management
- Company expects major level of funding and training support from the government to overcome barriers
- Company feels that its time a taken process and unwanted burden

The reservations expressed by key personnel primarily arise from limited awareness of Industry 4.0 and cloud technologies within the manufacturing sector. Standardization of procedure is complex and tedious due to the customized product. Consequently, the applicability of Industry 4.0 concepts to micro-scale enterprises remains constrained, as such technologies are still evolving and present significant challenges when applied to environments characterized by extensive product customization.

DISCUSSION

The comparative analysis of the three companies highlights Company Z as a potential candidate for future implementation of Industry 4.0 and cloud technologies. Unlike the other firms, Company Z has not yet adopted enterprise resource planning (ERP) systems such as SAP, thereby necessitating a comprehensive assessment prior to technological integration. Critical factors to be examined include organizational culture, employee skills and educational background, infrastructural readiness, and the availability of computer-aided software for design, manufacturing, planning, and engineering.

Resistance to technological adoption often arises from employee unawareness or apprehension regarding software applications, which can hinder implementation. To overcome these barriers, initiatives aimed at enhancing worker efficiency, organizational productivity, and system quality must be prioritized through the adoption of advanced technologies. Encouraging employees to participate in workshops and seminars related to Industry 4.0 and cloud systems can foster greater interest and acceptance. Furthermore, it is imperative that top management develops a clear understanding of the benefits associated with digital transformation, as managerial awareness and commitment are essential for successful organizational change.

Computer-aided technologies (CAx), encompassing design, manufacturing, and engineering applications, require a unified platform to facilitate the exchange of product data in distributed and collaborative manufacturing environments. Establishing such a common platform is essential for the seamless integration of manufacturing information, ensuring consistency, interoperability, and efficiency across diverse processes. The integration of CAx systems enables organizations to bridge gaps between design and production, thereby enhancing coordination, reducing redundancies, and supporting advanced manufacturing practices aligned with Industry 4.0 [26-27].

One of the principal challenges in adopting cloud-based solutions lies in ensuring data security during the transition from the current business model to a new digital framework. At present, Company Y collects, processes, and analyzes data internally through its organizational servers. Subsequently, selected datasets are transferred to the cloud, as in the case of Company X, where geographically dispersed workstations necessitate remote accessibility.

However, such migration raises concerns regarding data governance. Cloud adopters may risk losing control over their own data, while providers can exert influence over critical business processes, leading to issues such as vendor lock-in or acquisition of cloud service providers. Data security threats therefore remain a significant obstacle for organizations seeking to implement new technologies, underscoring the need for robust safeguards and governance mechanisms during cloud integration [28].

CONCLUSION

Micro, small, and medium enterprises (MSMEs) can leverage IT-enabled solutions through cloud computing and cloud manufacturing on a rental basis, thereby minimizing capital investment while enhancing competitiveness in both product quality and process efficiency relative to larger enterprises. As evidenced in the case studies, operational efficiency has been significantly improved through measures such as enhanced system quality, increased worker efficiency, organizational productivity, and strengthened process capability. Notably, Companies X and Y reported approximately a thirty-percent improvement in operational efficiency following the adoption of Industry 4.0 practices.

These findings serve as a strong motivation for other MSMEs to embrace digital transformation. Beyond efficiency gains, the adoption of Industry 4.0 and cloud technologies fosters greater flexibility, scalability, and responsiveness to market demands. It enables real-time data integration across distributed production units, supports predictive maintenance of machinery, and enhances supply chain visibility. Furthermore, cloud-based solutions democratize access to advanced technologies, allowing smaller firms to overcome resource constraints and compete effectively with larger organizations.

For successful implementation, however, MSMEs must address challenges related to employee awareness, digital skill development, and organizational readiness. Structured training programs, workshops, and government-supported initiatives can play a pivotal role in reducing resistance to change and ensuring smooth adoption. Ultimately, the integration of cloud and Industry 4.0 technologies not only improves operational efficiency but also strengthens the long-term sustainability and resilience of MSMEs in an increasingly competitive industrial landscape.

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