

## IOT ENABLED SMART MANUFACTURING AND SUSTAINABLE PERFORMANCE IN MEDIUM SCALE INDUSTRIES OF NASHIK DISTRICT

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### **Abstract**

*The diffusion of Industry 4.0 technologies has accelerated the transition from conventional manufacturing systems to digitally integrated smart manufacturing ecosystems. Among these technologies, the Internet of Things (IoT) enables real-time monitoring, predictive maintenance, automation, and data-driven decision-making. This study examines the impact of IoT-enabled smart manufacturing on sustainable organizational performance in medium-scale manufacturing industries of Nashik District, Maharashtra. A pilot study involving 96 respondents was conducted to validate the research instrument. Reliability and sampling adequacy were assessed using Cronbach's Alpha, Kaiser-Meyer-Olkin (KMO) measure, and Bartlett's Test of Sphericity. The findings indicate significant improvements in operational efficiency, workforce productivity, and managerial decision-making following IoT adoption. However, cybersecurity risks, financial constraints, and skill shortages remain notable implementation barriers. The study concludes that IoT-enabled smart manufacturing contributes meaningfully to sustainable industrial performance while requiring structured strategic implementation.*

**Keywords:** *IoT, Smart Manufacturing, Sustainable Performance, Industry 4.0, Medium-Scale Industries*

### **1. Introduction**

Manufacturing industries are experiencing profound transformation under the influence of Industry 4.0 technologies. The integration of cyber-physical systems, digital connectivity, and automation has reshaped production processes and organizational structures (Hermann, Pentek, & Otto, 2016). At the core of this transformation lies the Internet of Things (IoT), which facilitates real-time data exchange among interconnected devices and systems (Gubbi et al., 2013).

IoT-enabled smart manufacturing allows firms to optimize workflows, predict equipment failure, reduce downtime, and enhance operational transparency. Manyika et al. (2015) highlight the substantial economic value generated by IoT in manufacturing through improved asset utilization and productivity. Similarly, Lee and Lee (2018) argue that IoT adoption strengthens decision-making capabilities by integrating analytics into operational systems.

Medium-scale manufacturing industries in Nashik District represent a significant component of regional industrial development. However, empirical evidence examining IoT adoption and performance outcomes in such regional contexts remains limited. This study addresses this gap by investigating the relationship between IoT-enabled smart manufacturing and sustainable organizational performance.

### **2. Theoretical Foundation and Literature Review**

This study draws upon Industry 4.0 theory and technology-performance linkage frameworks. Industry 4.0 emphasizes digital integration and intelligent production systems (Hermann et al., 2016). IoT functions as a foundational enabler of smart manufacturing by supporting real-time communication and predictive analytics (Tao, Cheng, & Zhang, 2018).

Research suggests that IoT adoption enhances operational efficiency and decision-making effectiveness (Brous, Janssen, & Herder, 2020). Dash et al. (2024) demonstrate that IoT positively influences manufacturing performance when supported by organizational capability.

However, adoption challenges persist. Cybersecurity vulnerabilities and financial constraints are widely reported barriers (Khan, Al-Khatib, & Vasilakos, 2021). Skill shortages further complicate effective implementation.

The literature thus supports a positive technology-performance relationship while emphasizing contextual constraints.

### **3. Objectives and Hypotheses**

Objectives:

1. To examine the impact of IoT-enabled smart manufacturing on operational efficiency.
2. To assess its influence on workforce productivity and managerial decision-making.

3. To evaluate its contribution to sustainable organizational performance.
4. To identify key barriers affecting implementation.

#### Hypotheses

H<sub>0</sub> : IoT-enabled smart manufacturing has no significant impact on operational efficiency.

H<sub>1</sub>: IoT-enabled smart manufacturing has a significant positive impact on operational efficiency.

H<sub>0</sub>: IoT adoption has no significant impact on sustainable organizational performance.

H<sub>2</sub>: IoT adoption has a significant positive impact on sustainable organizational performance.

H<sub>0</sub>: Cybersecurity risks, financial constraints, and skill gaps do not significantly hinder implementation.

H<sub>3</sub>: Cybersecurity risks, financial constraints, and skill gaps significantly hinder implementation.

## 4. Research Methodology

### 4.1 Population and Sample

The total number of medium-scale manufacturing industries in Nashik District is 368.

According to Krejci and Morgan (1970), a population of approximately 370 would require a sample size of around 186 respondents for full-scale analysis.

Population(N)=368

Required sample (as per table)  $\approx$  186

However, the present research represents a **pilot study** aimed at instrument validation prior to large-scale data collection. For pilot studies, 10–30% of the projected main sample is considered methodologically adequate for reliability testing and preliminary validation.

Twenty industries were selected, and five employees from each industry were surveyed. Of the 100 distributed questionnaires, four were incomplete and excluded, resulting in a final pilot sample of 96 respondents.

### 4.2 Sampling Technique

Stratified random sampling was employed to ensure representation across managerial and operational roles.

### 4.3 Statistical Tools

- Cronbach's Alpha (Reliability)
- Kaiser-Meyer-Olkin (KMO)
- Bartlett's Test of Sphericity

### 5. Pilot Study and Instrument Validation

A pilot study was undertaken to validate the reliability and structural adequacy of the research instrument. A total of 96 respondents from medium-scale manufacturing industries participated in this preliminary phase.

### Reliability Analysis

Cronbach's Alpha was used to assess internal consistency among the measurement items.

- Organizational Performance:  $\alpha = 0.943$
- Organizational & Employee Performance:  $\alpha = 0.823$
- Competitive Advantage:  $\alpha = 0.833$

The alpha value of 0.943 for organizational performance indicates excellent internal consistency, suggesting that the items measuring operational and strategic outcomes were highly correlated. Similarly, the values above 0.80 for other constructs demonstrate good reliability, exceeding the commonly accepted threshold of 0.70 for social science research. These results confirm that the questionnaire items consistently measure the intended constructs.

### Sampling Adequacy and Factor Validity

The Kaiser-Meyer-Olkin (KMO) values ranged from 0.661 to 0.881. A KMO value above 0.60 is considered acceptable for factor analysis, while values above 0.80 are regarded as meritorious. Therefore, the sampling adequacy for this study is statistically satisfactory.

Bartlett's Test of Sphericity was statistically significant ( $p < 0.001$ ) across constructs, indicating sufficient inter-item correlations for factor extraction. This confirms that the data structure is appropriate for further analysis and supports the construct validity of the instrument.

Overall, the pilot study establishes that the measurement framework is both reliable and statistically sound for assessing the impact of IoT-enabled smart manufacturing on organizational performance.

## 6. Results and Discussion

### 6.1 Operational Efficiency

Approximately 78% of respondents reported enhanced workflow automation due to IoT integration. Automated monitoring reduced manual intervention and process delays. Additionally, 65% observed operational cost reductions, largely attributed to predictive maintenance and optimized resource allocation.

These findings support H<sub>1</sub> and correspond with Manyika et al. (2015), who note that IoT enhances asset utilization and process efficiency.

### 6.2 Workforce Productivity and Decision-Making

Seventy percent of employees indicated improved productivity, citing reduced repetitive tasks and improved system coordination. Moreover, 80% of managers reported faster and more accurate decision-making enabled by real-time data dashboards.

These results validate H2 and align with Lee and Lee (2018), who emphasize IoT's role in enhancing managerial effectiveness.

### 6.3 Implementation Challenges

Forty percent of respondents identified cybersecurity concerns as the primary barrier. Increased system connectivity raises exposure to potential digital threats (Khan et al., 2021). High initial investment costs were cited by 30%, while 20% reported insufficient technical skills as a constraint.

These findings support H3 and highlight the importance of strategic readiness.

### 7. Conclusion

The study confirms that IoT-enabled smart manufacturing significantly enhances sustainable organizational performance in medium-scale industries of Nashik District. Operational efficiency, workforce productivity, and managerial effectiveness improved following IoT integration.

However, addressing cybersecurity preparedness, financial planning, and workforce upskilling is essential for long-term sustainability. The findings provide preliminary empirical evidence supporting the strategic value of smart manufacturing in regional industrial ecosystems.

### 8. Scope of the Study

This study examines the impact of IoT-enabled smart manufacturing on sustainable organizational performance in medium-scale manufacturing industries located in Nashik District, Maharashtra. It focuses specifically on IoT as an enabling Industry 4.0 technology and does not analyze other advanced technologies independently. The research considers both managerial and employee perspectives to assess operational efficiency, productivity, decision-making effectiveness, and competitive sustainability. As a pilot investigation, the study primarily aims to validate the research instrument and generate preliminary empirical insights for a larger future study.

### 9. Limitations of the Study

The study is based on a pilot sample of 96 respondents, which is adequate for preliminary validation but does not represent the full recommended sample size for the population of 368 industries (Krejcie & Morgan, 1970). The findings are geographically limited to Nashik District and

may not be fully generalizable to other regions. Since the study follows a cross-sectional design, it does not capture long-term performance changes. The data are based on self-reported responses, which may involve perceptual bias. Additionally, the study focuses solely on IoT-enabled smart manufacturing and does not examine the combined effects of multiple Industry 4.0 technologies or apply advanced statistical modeling techniques.

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