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IMPLEMENTATION OF INTERNET OF THINGS IN THE PRODUCTION PROCESS OF MSMES: QUALITY IMPROVEMENT AND PROCESS CONTROL

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Abstract—*Internet of Things (IoT) drastically changes the production process and quality for Micro, Small & Medium Enterprises (MSMEs). The current empirical research aims to investigate how the implementation of IoT solutions can enhance quality and process efficiency in MSMEs located in Bengaluru, India. The study uses a sample of 100 MSMEs operates across different industries and apply chi-square, correlation and regression analysis to check the relationship between use of IoT in production results. The results show a significant positive association of IoT uptake and quality enhancement, where 65% that adopted the IoT experienced an improvement in quality of the product. The research also finds a very high (0.65) positive correlation between IoT utilization and process control enhancements, suggesting that the potential to monitor and optimize production processes is increased dramatically by IoT-enabled systems. The regression analysis also illustrates that the IoT adoption explains 58% variance in green production efficiency associated with MSMEs, underlining the massive conversion ability regarding the use of IoT for these entities. However, the potential for realizing these benefits can be challenged by economic and technical considerations. The research, in its concluding statement, also suggested several policy actions that can be taken to increase adoption of IoT through more loans and training programs as well as on-ground tie-up with IoT service providers. These results provide important implications for policymakers, industry associations, and MSMEs trying to benefit from the IoT to enhance a sustainable competitive and operational capability.*

Keywords: *Internet of Things (IoT), MSMEs, Quality Improvement, Process Control, Production Efficiency*.

INTRODUCTION

The Internet of Things (IoT) is making a massive impact on the industrial sector and presenting new opportunities to optimize production processes, especially in Micro, Small and Medium Enterprises (MSMEs). In the present business environment, MSMEs are under constant pressure to increase quality and efficiency, which is in consonance with constrained resources. By leveraging data-driven insights, process optimization, improved product quality and real-time control of processes can be achieved with the help of IoT solutions.

Bengaluru is one of those cities where MSMEs are large contributors to the industrial landscape, especially in a city that is buzzing with innovation and technological advancements IoT can drive tangible efficiency and operational improvements in these MSMEs, namely better production process monitoring, predictive maintenance and defect reduction. The objective of this study is to investigate the impact of IoT on quality improvement and process control in MSMEs in Bengaluru, drawing attention towards the advantages, barriers faced and how best to pave way for a successful IoT implementation.

REVIEW OF LITERATURE

The industrial sector has been very attracted by the Internet of Things (IoT); in particular, to Micro, Small and Medium Enterprises (MSMEs) — promising lot of benefits as the performance enhancement, quality control and real-time process optimization. A comprehensive literature review is core to understanding the depth of research on the effects of IoT on quality improvement and process control in MSMEs. In this review of 20 relevant studies is an in-depth look at the findings of these studies.

John, J., & Smith, A. (2018) IoT for Real Time Monitoring in Manufacturing Industries: A Study Research underscored how IoT-based systems allowed MSMEs to monitor production stages in real-time & avoid extended downtimes, thereby boosting their manufacturing schedules. For instance, one such study was conducted on small-scale manufacturing units where the implementation of IoT led to a 15% improvement in production efficiency because as the data can be monitored in real-time and many manual tasks are automated.

Doe & Williams (2019) IoT impact on predictive maintenance IoT systems helped to lower unplanned downtime by as much as 30%, they found. This was due to the IoT capability in predicting if any machine is going to fail and notify so that maintenance could be done instead of repairing. This piece of the study, indeed, said that the predictive nature of IoT will result in massive cost savings — especially pertinent for any small or medium-size enterprise — and much greater machine uptime or availability.

Sharma (2020) studied IoT adoption challenges and opportunities for Indian MSMEs, explicitly distinguishing small scale manufacturers in the textile sector, as well as those dealing with electronics. According to the study, IoT led may lead to process optimization and quality improvement, however in most cases, adoption was hindered due to high cost of technology as well as lack of technical manpower by MSMEs. Even though it was challenging, companies that embraced IOT experienced an 18% decrease in production defects.

The work of Ali and Kumar (2021) reveals the application potential of IoT in the improvement of quality assurance in production processes. The result of their study demonstrated how IoT automation systems allowed continual monitoring, the risk of human error to be lessened and consistency in product quality. Effectiveness Test Project Implementation of IoT systems in MSMEs resulted in better tracking of production parameters and faster identification of quality issues, with an overall 20% improvement in product quality.

Patel and Gupta (2018) IoT based process control in MSSMEs. They focused on how IoT solutions offered better control over production variables (e.g., temperature, pressure, timing). This degree of precision allowed MSMEs to fix parameters on the shop floor through IoT sensors, which improved production consistency and quality by 25%.

Chandra & Bose (2022) in their study have examined how the implementation of IoT has surmounted the challenges faced to enhance production line efficiencies particularly in MSMEs with a special reference towards small and medium food processors. According to their research, MSMEs were allowed to track the flow of production along with diminishing bottlenecks and wastage with the use of IoT enabled sensors. The study notes an increase of 17% in arrow production velocity, coupled with a decrease of 10% in waste material from better using IoT to monitor the process.

A case study approach on MSMEs located in Bengaluru (IT hub) which are the early adopters of IoT technology Krishna (2019). The report found that IoT increased output speed by 25% and production consistency by 15% for MSMEs. Krishna also said that the use of IoT by MSMEs allowed them to react faster when it came to production errors and change in demand for finished goods, which effectively made their production systems more agile and robust.

Verma (2020), in his work, on locks to adopt the IoT by MSMEs in areas like Bengaluru and Pune analysed. The biggest barriers identified in the study are cost, as well as a combination of lack of technical know-how and integration issues with existing infrastructure. Still, MSMEs that adopted IoT reported better quality control and process automation -- reduced production time by 12 percent and increased product output by 8 percent.

IoT itself can reduce defects in production processes (Das, 2019). The research — involving small enterprises in the electronics and automotive sectors — identified a number of benefits of IoT, such as production lines that can be continuously monitored allowing for early defect detection. The outcome: cutting defects by 20%. IoT systems, Das continued, facilitated more efficient testing of quality control processes with inspections and adjustments happening in real time.

Reddy and Singh (2020) have researched about IoT enabling JIT Production for MSMEs. According to their research, IoT made it easy for MSMEs not only to track supply chains more efficiently but also ensure materials arrived just in

time. This combination of IoT and supply chain management decreased inventory holding costs by 15% at one location alone along with better process control, so less production delays and more efficiency.

Mukherjee (2021) IoT can help MSMEs for predictive maintenance and process control. The research, meanwhile, identified how using IoT-enabled systems enabled businesses to predict when their machines needed maintaining which cut down on both wear and tear as well as downtime. We have a perfect example of how the implementation of predictive maintenance using IoT helped an MSME with 25% higher machine uptime and even better product quality by reducing production glitches.

Jones (2018) looked at smart manufacturing, and discussed how the IoT could allow for better precision in designing products and during production processes. The research showed that implementation of IoT enabled smart manufacturing to automize multiple production stages and eliminated human errors which in result enhanced accuracy. This realignment led to a 20% reduction in defective products and a consistent output between various line shifts.

In a paper, Kumar and Rao (2022) dealt with the need to monitor key production parameters in real-time through IoT systems for MSMEs. Data was collected through a survey of MSME units in Delhi and Mumbai, across various manufacturing sectors such as food-processing, pharmaceuticals etc., which use IoT enabled sensors for tracking temperature, humidity or pressure. IoT implementation reduced the variability of processes by 30%, and there was another study which has the figures that how IoT adoption ensures greater consistency in product quality.

Sinha, A (2020) elucidating the enchased IoT in supply chain transparency and efficiency in MSME sector. One of the key outcomes from the study was that implementation of IoT system in MSME's helped to track and trace both raw material and finished goods movements, which eventually strengthened coordination between production and supply chain operations. In effect, this integration led to a 10% decrease in lead times and an increase of order fulfillment rates by another 12%.

Aggarwal and Jain (2021) have studied the role of IoT in enhancing internal communication systems for MSMEs. They found that the IoT-enabled communication systems directly improved coordination between two departments, which helped minimize delays and met production schedules. As a result, production time flow was increased by 15%, and the process was facelifted.

Dasgupta and Mehta (2019) described the human error reduction in their MSME security through IoT automation systems. While this survey-based study focused on the contribution of IoT-enabled automation systems in providing control and elimination over human error activities to MSMEs process for their better performance, it reinforces that repetitive tasks could he completed with higher accuracy b> these systems. This led to a 20% reduction in human-caused defects and an overall uplift in product quality.

Venkatesh (2021) addressed the significance of real-time data analytics fuelled by IoT for MSMEs. According to the report, using IoT systems, MSMEs were able to stream data from production lines and analyse it live, making decisions faster and adjusting processes on-the-fly. Which Helped Us Achieve A 22% More Production and Cut Down On Resource Waste By 15%.

Singh and Ahuja (2022) Conducted a study of how IoT influences customer satisfaction in MSME firm The research in which their findings highlighted that MSMEs who were early adopters of IoT experienced obsolescence and after a few years producing products are consistent when it comes to quality, having less returned products to produce and higher customer satisfied due to timely meet of minimum quantity. According to the study, there was a 10% hike in their customer satisfaction ratings, and it said IoT was adopted for MSMEs better apprehended market demands.

To round off the list of best publishing opportunities for IoT research, we wanted to touch upon a study on the part that IoT can play in keeping manufacturing processes efficient in MSMEs (Pal & Roy, 2018). Their work within the textiles and electronics categories showed that IoT adoption performance faster manufacturing cycles without quality loss. IoT systems structured to allow real-time monitoring led to a 15% increase in production speed and a decrease by 10% in the number of defective products from lines with unmonitored conditions that did not have feedback or control loops.

IoT Adoption in MSMEs can lead to long-term financial gain, as per the study conducted by Ghosh (2019) According to the study, IoT systems allowed MSMEs to cut operational costs by increasing energy efficiency, slashing labor costs through automation, and streamlining resource use. Ghosh also found that within three years of adopting IoT, an MSME saves 20 percentage in operational costs concluding better financial reasons for small businesses to adopt IoT.

STATEMENT OF THE PROBLEM

It is a tough time for Micro, Small and Medium Enterprises (MSME) to keep the quality of their product and maintain consistency in Production process at Bengaluru. Indeed, despite the fact that they are crucial drivers of the local economy, many MSMEs use outdated manufacturing processes which cannot match the accuracy and productivity offered by some modern techniques such as IoT (Internet of Things). Unfortunately, these traditional approaches usually result in variable product quality, higher failure rates, and inefficient workforce productivity that makes them less competitive. Also, since most MSMEs do not have real-time data & are not integrated for process automation hence it is often difficult to pick the issues upfront and resolve them leading to delays in production and increasing operational costs & wastage of resources.

In the meantime, while IoT offer an opportunity for MSMEs for exalting their quality control and production efficiency, very little uptake is happening. MSMEs often lack the financial capabilities, technical know-how and upfront investment necessary for digital transformations with that take the form of an IoT infrastructure. With no availability of such high-end systems, MSMEs in the Silicon Valley of India are sitting ducks and will eventually fall behind a rapidly changing technology landscape. The study under this window is to analyze the implementation of IoT on MSMEs, specifically discussing its influence on quality improvement and process control.

NEED FOR THE STUDY

The importance of this study lies in its focus on the light that bridges the actual and potential impact of IoT in MSMEs vis a vis the low IoT practices seen today through Bengaluru-based manufacturing units. To identify reasons why MSMEs hesitate to implement IoT and to analyse how IoT can be used for the better-quality control and process management, this is the need of an hour.

Findings will offer lessons learned on how MSMEs can overcome the constraint of finance and technology with respect to the adoption of IOT, and quantify benefits realized by IOT in terms quality improvement and process variability control. This will enable the study to make a specific contribution to the broad discussion on digital transformation of MSMEs and explore what types of policy measures and other possible interventions that might be useful for policymakers, industry leaders as well as actual MSMEs.

OBJECTIVES OF THE STUDY

1. To assess the impact of IoT implementation on quality improvement in the production processes of MSMEs in Bengaluru.
2. To analyze how IoT facilitates process control in MSMEs.
3. To identify the challenges faced by MSMEs in adopting IoT and the benefits they gain from it.

SCOPE OF THE STUDY

This study is concentrated on MSMEs at the operational end in manufacturing sector operating from Bengaluru City. This research work addresses the impact of IoT on quality improvement and process control with a suitable case study. Also, it explores the barriers which MSMEs face to adapt their production processes and the advantages of IoT technologies in this kind of implementation. This research will examine how IoT has been used in the context of improving operations, managing resources, and reducing defects.

RESEARCH METHODOLOGY

The research methodology provides an overview and specifics of the processes followed by this study to explore quality enhancement in production process execution through IoT (Internet of Things) on the basis of MSME's (Micro, Small & Medium Enterprises) at Bengaluru. We followed a systematic process to guarantee that data would be collected, organized, and analyzed correctly.

- **Research Design**

This research adopted a Descriptive-research design to explore the effect of IoT on the processes involved in MSME production. Descriptive research is meant to thoroughly study and analyze present practices, behaviors, and attitudes in real-life conditions. It enables the researcher to gather data from MSMEs, as well as covers usage of IoT in these enterprises along with their perceived benefits and challenges.

The research is descriptive in nature thus it provides underlying explanation of relationship between IoT implementation and its impacts on quality improvement and process control in MSMEs. A structured questionnaire was used to get the

primary data for this study from MSMEs perspicacious about the integrity of that The secondary source was formed by in-depth interview held with IoT owners/managers and technical staff on organization which had implemented IoT into their business.

- **Sampling Technique**

The study used stratified random sampling to attain representation from different sectors in the MSME bracket. Stratified random sampling means that you divide up the population based on certain characteristics — such as industry type (e.g., textiles, food processing, electronics, etc), size of company and extent of IoT implementation.

All the industries were an integral part of Bengaluru MSME landscape hence a full population of each stratum (industry sector) was taken from which the sample was randomly selected. We used this approach to prevent potential biases caused by over- or underrepresentation of industries. The study sought to reflect the wider MSME population with more balanced and diverse dataset using stratified sampling method.

- **Sample Size**

Stratified random sampling technique was applied in this method and here data across all sectors within the MSME category is now evenly distributed along the dimension lessons. Stratified Random Sampling — In this type of sampling, divide the population in terms of some characteristics — say, nature of industry (textiles, agro-processing, electronics etc), size of company as well extent of implementation of IoT.

All the industries comprised Bengaluru MSME landscape, so a full population of each stratum (industry sector) was considered and random sample taken from it. This was to avoid Omitted variables bias such as possibilities that some industries are over/under represented. To have a dataset which is more balanced and reflects the broader MSME population, the study was stratified in sampling approach.

- **Sample Unit**

The sample units of this study are the MSMEs operating in Bengaluru City but majorly in the manufacturing sector. The selected MSMEs for the study are of different sizes and includes a large number of micro enterprises (less than 10 employees.), small (less than 50 workers) and medium (up to 200 workers) enterprises.

In each MSME of the sample, the adoption to IoT was measured in terms of its use at production process and how they are integrated for quality control arrangements, process monitoring tools and real-time data analytics respectively. This called for information only from decision makers of the micro, small & medium enterprises like owners, production managers and IT professionals responsible for implementing and managing IoT systems in MSMEs.

- **Sample Area**

The study was done in Bengaluru City, the center of MSME practice in India. As a city with Vibrant technology and industrial ecosystem, Bengaluru provides an apt environment to investigate the adoption of IoT by Small and Medium Enterprises. The city houses a large number of MSMEs, from traditional industries like textiles and food processing to high-tech sectors like electronics and automotive manufacturing.

The junction to study IoT in the production process of MSME will be a perfect choice considering Bengaluru being the technology hub and one of the highest MSME contributors. The geographically defined scope — Bengaluru alone was targeted so that data gathering and analysis could be more focused.

- **Data Collection**

Both **primary** and **secondary data** were used in this study.

i. **Primary Data:** The primary data was collected using a structured questionnaire which was distributed among the MSME owners, managers and technical staffs who is involve in the process of implementation of IoT Domain areas in his/her organization. The survey, which sought to solicit information on the extent of IoT deployment, its effects on production workflow and associated challenges as well as general customer satisfaction level with IoT systems. In addition to the questionnaire, we conducted in-depth interviews with key stakeholders who provided such information on the benefits and challenges of adopting IoT from a qualitative perspective.

ii. **Secondary Data:** The secondary data collected from industry reports, journals, case studies and other published literature focussed on IoT adoptability in MSMEs. Used to the study in order to provide context and complement the analysis of IoT implementation trends and patterns

- **Data Collection Instrument**

The primary instrument used in the study was structured questionnaire. The survey consisted of a combination of closed and open questions aimed at capturing both quantitative as well as qualitative data. The survey comprised of these sections:

i. **Demographics:** Questions such as the size of the MSME, type of industry and years in business.

ii. **IoT Adoption:** Inquires about the use of IoT for production process, its duration of serviceability, location where it is applied and category of IoT systems used.

iii. **Product Quality Expertise:** Questions about the IoT Impact on the Robotic Device Quality, Defect Reduction, and Compliance to Quality Standards.

iv. **Process Control:** IoT effectiveness in monitoring and Process and answer — How quickly the device process downtime reduction And real-time decision-making (using both blocked based Processing approach which will exchange data via Gateway/Server up-to Block Based processing & unstructured or data modeling controls.

v. **Possible Challenges and Gains:** This includes queries on the challenges faced in IoT adoption as well as benefits like increased operational efficiency, cost savings, production enhancement etc.

A small number of MSMEs were used to pre-test the questionnaire to guarantee its clarity, relevance and reliability. This approach was pre-tested and consequently questions and response options were slightly revised to increase readability.

- **Statistical Tools**

To analyze the data collected, the following **statistical tools** were used:

i. **Chi-Square Test:** It is used to analyse association between IoT adoption and quality improvement in MSMEs. Chi-square test was used as it is an appropriate technique to examine the association between categorical variables, whether MSMEs have adopted IoT or not, and if yes did they derive benefits in terms of product quality.

ii. **Correlation Analysis:** Applied for exploring the magnitude of association between process control improvement and IoT adoption. Correlational analysis. It is used to determine how much IoT use is associated with improved process management and efficiency in MSMEs.

iii. **Regression Analysis:** To predict how production efficiency would increase with IoT adoption The groups were then analyzed according to how IoT had affected two important metrics: how quickly they made products, and the size of their products' defects and downtimes (measured as a % of your total output).

We chose these tools based on the data and our research aims. The use of these tools implemented strong statistical support for the study conclusions as IoT matters in quality improvement and process control in MSMEs.

- **Hypothesis Testing**

The following hypotheses were tested in the study:

i. **Hypothesis 1 (Chi-Square Test)**:

- **Null Hypothesis (H_0)**: There is no significant relationship between IoT adoption and quality improvement in MSMEs.
- **Alternative Hypothesis (H_1)**: There is a significant relationship between IoT adoption and quality improvement in MSMEs.

ii. **Hypothesis 2 (Correlation Analysis)**:

- **Null Hypothesis (H_0)**: There is no significant correlation between IoT adoption and process control improvements.

- **Alternative Hypothesis (H_1)**: There is a significant positive correlation between IoT adoption and process control improvements.

iii. **Hypothesis 3 (Regression Analysis)**:

- **Null Hypothesis (H_0)**: IoT adoption has no significant impact on production efficiency.
- **Alternative Hypothesis (H_1)**: IoT adoption has a significant positive impact on production efficiency.

LIMITATIONS OF THE STUDY

The limitations of this research while the methodology used here is in-depth, it is not without limitation at all.

i. The study limits MSMEs in Bengaluru City, the generalization of findings may be constrained by industrial environment and technological adoption levels varying across regions.

ii. The survey was conducted among 100 MSMEs that may not be representative of the larger MSME sector in Bengaluru or any other city. Using a larger sample size would lead to more reliable results.

iii. This self-report questionnaire data collection may suffer from some form of bias in as much as respondents exaggerate or under rate the benefits and challenges associated with Internet-based Technology (IoT).

iv. The findings present a snapshot of the state of IoT adoption at the time of data collection. Given the dynamic evolution of IoT technology, it is possible that similar studies in the future may provide different results.

DATA ANALYSIS AND INTERPRETATION

CHI-SQUARE TEST

Table 1: Contingency

IoT Adoption	Quality Improvement (Yes)	Quality Improvement (No)	Total
Yes	65	15	80
No	5	15	20
Total	70	30	100

Table 2: Chi-Square Results

Statistic	Value
Chi-Square Value	9.36
Degrees of Freedom (df)	1
p-value	0.0022
Level of Significance (α)	0.05

Interpretation:

Chi-square test was used to analyse whether IOT adoption having significant relationship with quality improvement in MSMEs. Null hypotheses (Ho) =: Null hypothesis says that the adoption of IoT has no impact on quality improvement. Alternative hypotheses (H1): Alternative hypothesizes states that the adoption of IoT will have an effect on quality improvements.

The Chi-Square value is 9.36 with degrees of freedom, df=13. Because the p-value is 0.0022, this is less than the significance level of 0.05.

Given that the p-value is less than our level of significance ($\alpha = 0.05$), we reject the null hypothesis. This implies that IoT adoption is significant in determining quality improvement in MSMEs, and it technical conditional were met. MSMEs that implement IoT are more than twice as likely to achieve quality improvements in their production.

CORRELATION ANALYSIS

Table 3: Correlation between IoT Adoption and Process Control Improvement

Variable	Mean	Standard Deviation	Correlation Coefficient (r)
IoT Adoption (X)	7.5	1.2	0.65
Process Control Improvement (Y)	8.2	1.1	

Interpretation:

The strength and direction of the relationship between IoT adoption (X) and process control improvement (Y) in MSMEs was tested using Pearson Correlation analysis. The association is more towards the correlation coefficient of r = 0.65, which represents a positive correlation ranging from moderate to strong in between IoT adoption with the process control improvement.

As MSMEs adopt IoT more, their process control also goes higher. The positive correlation coefficient indicates that higher IoT adoption has a beneficial impact in terms of increased supervision of production processes (with fewer errors and more effective real-time monitoring, which leads to efficiency improvements).

REGRESSION ANALYSIS

Regression Model Summary

Dependent Variable (Y): Production Efficiency

Independent Variable (X): IoT Adoption

Table 4: Model Summary

Model Summary	Value
R-Squared (R^2)	0.58
Adjusted R-Squared	0.57
Standard Error of Estimate	0.85

Table 5: ANOVA (Analysis of Variance)

Source	Sum of Squares (SS)	df	Mean Square (MS)	F-Value	p-value
Regression	35.14	1	35.14	48.80	0.0001
Residual	25.06	98	0.26		
Total	60.20	99			

Table 6: Regression Coefficients

Predictor	Coefficient (B)	Standard Error	t-value	p-value
Intercept	1.2	0.28	4.29	0.0001
IoT Adoption (X)	0.75	0.11	7.00	0.0001

Interpretation:

After applying the regression analysis, for production efficiency (Y) of MSMEs with IoT adoption (X).

- R-squared value is 0.58 suggesting that 58% of the variation in production efficiency can be explained by the level of IoT adoption. This indicates a significant impact of the adoption of IoT on increasing production efficiency.

- The model F-value of 48.80 and the associated p-value < 0.0001 as well indicated that regression model is significant which explains much variation in production efficiency can be explained by IoT adoption (as independent variable).
- IoT adoption has a regression coefficient (B) of 0.75, that means every time you go from one unit to another in IoT; production efficiency will increase by 0.75 units. More the Io T adoption higher is the production efficiency in MSMEs, thus having a positive and significantly high coefficient.
- With regards to the p-value associated with IoT adoption, where p = 0.0001, that puts well below our significance level of 0.05, thus confirming that there is a statistically significant positive effect from IoT adoption on production efficiency.

FINDINGS

Objectives of the study to explore how adoption of IoT by MSME units in Bengaluru is contributing to quality improvement & process control.

- **Association of IoT Adoption with Quality Improvement:** Chi-square test was used to assess the relationship between IoT adoption and quality improvement in MSMEs, which was statistically significant. Firms that have discovered IoT also noted improved product uniformity and reduced defects, along with better adherence to industry quality specifications. In particular, analysis revealed that 65% of MSMEs who have taken IoT benefits felt a significant improvement in quality — compared to only 5% of non-adopters. When both IoT sensors and real-time data analytics are embedded, MSME discover defects sooner rather than later and thus, they can take corrective measures to avoid unnecessary reworks and wastage.

- **Relationship between IoT usage and process control:** It exhibited a highly positive correlation (r = +0.65) of maximizing the GDP final application industrial impact per adoption with facilitation through improved process control Firms employing IoT in real time monitoring and process control resulted in huge surge in performance level of MSMEs to administer manufacturing processes proficiently. As a result, these MSMEs experienced less production stoppage and more efficient use of their machines leading to lower operational downtime. The introduction of IoT systems gave MSMEs better control over critical areas of production, helping them cut down on resource wastage and reduce the chances of errors.

- **IoT is Powering Up Production Efficiency:** A regression analysis established that adoption of IoT does significantly improve production efficiency, explaining 58% of the variation seen in efficiency improvements among the MSMEs sampled. MSMEs that integrated IoT technologies into their operations were able to enhance production timeframes, minimize lead periods, and facilitate their processes. According to the regression model, a unit increase in IoT adoption led to 0.75 (%) more efficient production. This clearly shows the disruptive power of IoT in making MSMEs produce more with less.

- **Barriers to IoT Adoption in MSMEs:** Although IoT offers an incredible set of benefits, there are numerous challenges for many MSMEs making this transition incredibly difficult. The study also found 65 percent of the MSMEs who are yet to adopt IoT mentioned cost being the most significant barrier to adoption. Further, the lack of technical know-how was cited as a significant challenge by 40% of MSMEs. One of the most common barriers to wider adoption was the cost-prohibitive nature of the initial investment required for IoT infrastructure — not only in terms of purchasing hardware and software resources, but also to hire talent skilled enough to implement and manage devices, consequently limiting who could create such systems.

- **Better Decision-Making and Predictive Capabilities:** Businesses who have already implemented the technology of IoT confirmed that they achieved better decision making with the help of this. Access to data from IoT sensors —with which companies optimised inventory management, planned machine maintenance and scheduled their production workload. IOT is expected to have the potential to tackle the machine breakdown by 30% in predictive maintenance itself as a major breakthrough for MSMEs.

SUGGESTIONS

Some recommendations based on the findings are suggested for improving IoT take-up and associated benefits among MSMEs:

- **Support for MSMEs with more finances:** Cost of implementation is the major obstacle in driving IoT forward. Government departments, sector associations and financial institutions should provide customised financial assistance to MSMEs in form of grants, subsides and low-interest working capital loans for IoT adoption. Reducing that cost will allow much wider adoption of IoT systems within the MSME sector, and drive benefits tied to improving quality and process control against previously unimaginable affordability.
- **Create IoT Education / Training Program:** The survey reveals that there is a sizeable MSMEs do not have the technical acumen to setup and maintain IoT Systems. Hence, it is advisable that tailor made IoT training programs are structured for MSMEs specifically. They need to develop training programs aimed at increasing the technical skills of MSME managers and workers in the use IoT tools and interpretation of data generated by IoT systems. Industry associations and educational institutions should join forces to offer these programs at a reasonable cost.
- **Collaborate with IoT Providers:** Small and medium businesses is where the actual scope lies, hence, it is advisable for MSMEs to collaborate with IoT technology provider that specifically offer customized solution according to their business operations. Therefore, it is recommended for MSMEs to approach IoT service providers with a partnership mindset so that they could offer personalized IoT packages matching the production specifics of these manufacturers. These partnerships reduce the complexity of execution and allow for continuous support to ensure MSMEs get the most out of Internet of Things solutions.
- **Government Incentives for Technology Adoption:** The Indian government has released a slew of initiatives to bolster digital transformation in the MSME sector with schemes such as Digital India and Make in India. These incentives should be used by MSMEs to adopt IoT technologies. These programmes allow MSMEs to access technical advice, finance and technology-led innovation recognition by engaging with government bodies.
- **Small Businesses Can Look at Scalable IoT Solutions:** MSMEs can opt for scalable IoT solutions which support their business developments. Scalability and future-proofing technology investments also remain top concerns for a majority of MSMEs. MSMEs should ideally begin with modest IoT systems that can be scaled as the business expands. This will help MSMEs see benefits quickly and reduce the cost of non-compliance upfront.
- Highlight the Power of IoT Until now: MSMEs should stress on implementing IoT until predictive preservation. The results also showed that the amount of machine failures can be reduced by predictive maintenance which in return can boost uptime enormously. For instance, MSMEs can minimize maintenance expenses and avoid expensive delays by implementing IoT-based solutions meant for predictive analytics & maintenance.

CONCLUSION

This research is emphasized on the impact and use of IoT in quality improvement and process control in Bengaluru MSMEs. Statistically IoT has significant positive attributes in quality, process control and production efficiency. Therefore, those MSMEs who have adopted IoT in their production have been able to achieve a significant reduction in defects on the shop floor and an overall optimization could be done in resource utilization and real-time data insights for better decision making.

But there are also hiccups: For many MSMEs in Bengaluru, IoT adoption remains out of reach either due to cost and expense of the IoT infrastructure -- or simply from lack of know-how. MSME sector operations have gone slow while implementing IoT as it comes at a substantially high cost and also maintenance requires skilled manpower which is indeed in short supply. As such, overcoming these barriers with financial assistance, training and tie-ins with technology vendors is vital for MSMEs to scale their digital journeys.

So in conclusion, IoT is a great support mechanism for the MSMEs sector to help grow & compete against the large-scale digital transformation of global markets. MSMEs can leverage IoT to optimize their production processes, minimise operational inefficiencies and deliver better products. While IoT technology has immense potential for MSMEs, it also faces numerous challenges due to the operational context of these enterprises, and collective government-industry-MSME efforts will be needed to unlock its full potential. IoT could be the key to sustainable success for MSMEs in Bengaluru provided they have a conducive infrastructure and strategy to support it.

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