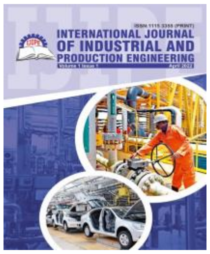


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# Cost-Benefit Analysis of IoT-Enhanced Maintenance: A Quantitative Assessment for Large-Format Printing Machine

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## Abstract

This paper presents a comprehensive cost-benefit analysis of implementing Internet of Things (IoT)-enhanced maintenance strategies for large-format printing machines, with a focus on the Yinghe 6-feet printing machine at Chuxog Prints Limited, Awka, Nigeria. The study compares data before the implementation of IoT (referred to as pre-IoT) and after the deployment of IoT devices (referred to as post-IoT). By analyzing pre-IoT data (before IoT implementation) and post-implementation data, the study demonstrates significant reductions in maintenance frequency, technician labor costs, and machine component replacement expenses. Notably, the IoT system aided in minimizing wasted flex material and improved ink efficiency. Key findings include a 49.4% reduction in average monthly technician labor costs, a 93.9% reduction in average monthly machine component replacement costs, and an 87.6% reduction in wasted flex material. These findings have profound implications for industries relying on large-format printing machines, showcasing the potential for cost savings, increased efficiency, and extended equipment lifespan through IoT adoption. The paper concludes with a strong recommendation for organizations to consider IoT-enhanced maintenance strategies based on the observed empirical evidence, contributing invaluable insights to the optimization of maintenance practices in industrial settings.

**Keywords:** Industry 4.0; Printhead; Cloud Computing; Condition Monitoring.

## 1 Introduction

In the ever-evolving landscape of industrial machinery, the adoption of cutting-edge technologies has become instrumental in enhancing operational efficiency and extending the lifespan of critical equipment (Mourtzis et al., 2021). Large-format printing machines, characterized by their intricate components such as printheads, motors, and ink delivery systems, are essential for industries reliant on visually compelling graphics, textile imaging and signage. The traditional maintenance paradigm, rooted in scheduled routines and reactive interventions, has often led to operational disruptions, elevated maintenance costs, and suboptimal resource utilization (Dong et al., 2017)

Recognizing the limitations of conventional maintenance practices, there has been a growing drive to explore Internet of things (IoT)-driven solutions that promise to revolutionize the maintenance landscape. IoT devices embedded within these printing machines facilitate the continuous monitoring of critical components, enabling the collection of real-time data on performance, wear and tear, and potential failure points (Cao et al., 2021, Mgbemena et al., 2020; Mgbemena & Okeagu, 2023; Okeagu & Mgbemena, 2022; Onuoha et al., 2022). In our investigation of the Yinghe 6-feet large-format printing machine at Chuxog Prints Limited, Awka, Nigeria, we deployed an IoT-based maintenance system. This system monitors critical components, including ink levels (cyan, magenta, yellow, and black), printhead media gap, printhead distance coverage, y-motor count, and machine earthing. The wealth of data captured empowers the maintenance team to shift from a reactive stance to a proactive and predictive approach, enabling the anticipation of issues before they escalate and optimizing resource allocation. This strategic shift aligns with the principles highlighted by Mobley (2002).

The primary objective of this research is to conduct a cost-benefit analysis of the implementation of IoT-enhanced maintenance strategies for large-format printing machines with a focus on the Yinghe 6-feet printing machine at Chuxog Prints Limited, Awka, Nigeria. By comparing data from the period before IoT integration (January to December 2021, January to December 2022) with data obtained after the deployment of IoT devices (January to July 2023), this study aims to quantify the impact on maintenance costs, component replacements, maintenance labor expenditures, and overall operational efficiency.

## 2 Literature Review

The advent of IoT technologies has led to a paradigm shift in the way industrial maintenance is conceptualized and executed. According to Bhat et al., (2007) IoT facilitates the creation of a digital ecosystem where physical components are seamlessly connected, allowing for real-time monitoring and data-driven decision-making. Nižetić et al., (2020) emphasize that continuous data collection allows for the early detection of anomalies, potential failures, and wear and tear, enabling timely interventions to prevent operational disruptions. The application of IoT in maintenance strategies for printing machinery has garnered attention in recent research. The significance of deploying IoT for condition-based maintenance is studied by (Lai et al., 2019) where the health of machine components is continuously assessed. In the case of large-format printing machines, condition-based monitoring can be extended to critical parameters such as ink levels, printhead gaps, and motor counts, providing a holistic view of the system's performance.

The significance of IoT in the maintenance of printing machinery has been acknowledged in recent research. For instance, Lai et al. (2019) emphasize the importance of deploying IoT for condition-based maintenance, continuously assessing the health of machine components. However, the specific nuances of large-format printing machines, including considerations such as ink levels, printhead gaps, and motor counts, demand a tailored exploration. Chianese et al. (2021) stress the need for comprehensive cost-benefit analyses to justify investments in IoT technologies. Their risk and priority model for cost-benefit analysis provides a relevant framework for evaluating the economic implications of IoT-enhanced maintenance. Thomas (2018) further emphasizes the importance of considering long-term benefits and overall return on investment in the context of advanced maintenance strategies, providing insights applicable to the current study. Shamayleh et al. (2020) present an IoT-based predictive maintenance strategy, showcasing significant diagnostic and repair cost savings. While their focus extends to broader industrial contexts, the principles can be extrapolated to the specific challenges and opportunities posed by large-format printing machines.

As organizations consider the adoption of IoT-enhanced maintenance, a crucial aspect is the evaluation of costs and benefits. Chianese et al., (2021) stress the need for comprehensive cost-benefit analyses to justify the investment in IoT technologies. They present a risk and priority model for cost-benefit analysis Additionally, Thomas, (2018) emphasizes the importance of considering long-term benefits and overall return on investment in the context of advanced maintenance strategies. The report extends further to identify the data needed for making such estimates and the feasibility of collecting the relevant data. Shamayleh et al., (2020) present an IoT Based Predictive Maintenance strategy, their approach provide significant diagnostic and repair cost savings that can reach up to 25% and an investment payback period of one year. While the advantages of IoT in maintenance are evident, it is essential to acknowledge the challenges associated with implementation, Compare et al., (2020) present issues such as huge cost of investment, data security, interoperability, and the need for skilled personnel as challenges to IoT-enabled maintenance.

In summary, the literature review highlights the transformative potential of IoT-enhanced maintenance. The ability to monitor critical components in real time, coupled with the potential for proactive interventions, positions IoT as a valuable tool in optimizing operational efficiency. However, the implementation of IoT in maintenance strategies requires careful consideration of costs, benefits, and the challenges posed by the complex nature of large format printing machines.

## 3. Research Method

The quantitative research method is employed in this study.

### 3.1 Data Collection

The study utilized maintenance datasets of a Yinghe 6feet large format machine. covering two distinct periods: January to December 2021 to January to December 2022 (pre-IoT deployment) and January to July 2023 (post-IoT deployment). Monthly records of quantities and costs associated with replaced components (e.g., dampers, printheads, y-motor) were collected for both periods. Also Data on the frequency of maintenance activities and corresponding labor costs were collected monthly. Finally**,** detailed records of consumables, including inks and flex media, were documented during the specified periods.

### 3.2 IoT Device Integration and Data Capture

The developed IoT device was implanted on the large-format printing machine to capture real-time data from critical components, including ink levels (cyan, magenta, yellow, black), printhead media gap, printhead distance coverage, and y-motor count and Machine earthing. Real-time data were transmitted to the company's server, where proprietary algorithms processed the information to facilitate informed maintenance decisions.

### 3.3 Cost-Benefit Analysis Framework

A tailored cost-benefit analysis framework was designed to assess the economic implications of adopting IoT-enhanced maintenance.

**3.3.1 Cost Analysis:** Direct costs related to maintenance activities, such as component replacements and maintenance labor expenses were quantified for both pre-IoT and post-IoT periods. Additionally, costs of consumables (Flex and Ink) for the periods were also considered.

$$\boldsymbol{ATLC} = \frac{\sum \mathbf{TLC}}{\sum \mathbf{M}} \tag{1}$$

**Where:**
ATLC represents the Average monthly Technician's Labor Cost
LC denotes the Technician's Labor Cost
And M is Months of the period under consideration

$$\boldsymbol{ARMC} = \frac{\sum \mathbf{RMC}}{\sum \mathbf{M}} \tag{2}$$

Where:
ARMC represents the Average Monthly Cost of Replaced Machine Components
RMC is the Cost of Replaced Components and
And M is Months of the period under consideration

$$\boldsymbol{AMCC} = \frac{\sum \mathbf{MCC}}{\sum \mathbf{M}} \tag{3}$$

**Where:**
AMCC represents the Average Monthly Cost of Consumables
LC denotes the Monthly Cost of Consumables
And M is Months of the period under consideration

**3.3.2 Benefit Analysis:** Tangible benefits, including cost savings on machine's component replacement and savings on maintenance labour cost were quantified. Also savings from reduced consumables (flex and ink) wastage/loss were computed with the equations.

$$\textbf{Savings on Technician's Labor Cost} = \boldsymbol{ATLC_{(pre-IoT)} - ATLC_{(post-IoT)}} \tag{4}$$

Where:

$ATLC_{(pre-IoT)}$ represents the Average monthly Technician's Labor Cost before IoT implementation.

$ATLC_{(post-IoT)}$ denotes the Average monthly Technician's Labor Cost after IoT implementation.

Equation 4 is also applicable in obtaining the savings on machine component replacement cost and consumable usage cost safe for replacing $\boldsymbol{ATLC_{(pre-IoT)}\ and\ ATLC_{(post-IoT)}}$ with $\boldsymbol{ARMC_{(pre-IoT)}\ and\ ARMC_{(post-IoT)}}$ **or with** $\boldsymbol{AMCC_{(pre-IoT)} - AMCC_{(post-IoT)}}$ **where applicable**

## 3.4 Software

Microsoft Excel and Power BI were employed in data recording, cleaning, analysis and visual representations.

## 4.0 Result

### 4.1 Maintenance Technician's cost/benefit

Major maintenance on the 6feet large format machine is outsourced to a Yinghe licensed technician. The number of times he made maintenance on the machine is represented in figure 1a, and the various cost for the maintenance is represented in figure 1b.

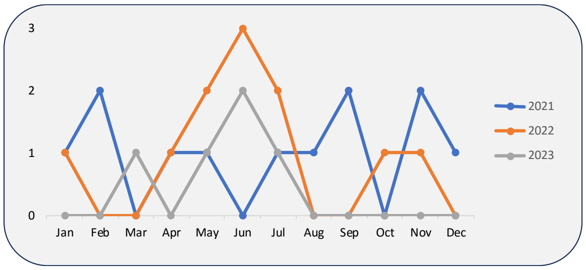


**Figure 1a: Trend of frequency of maintenance**

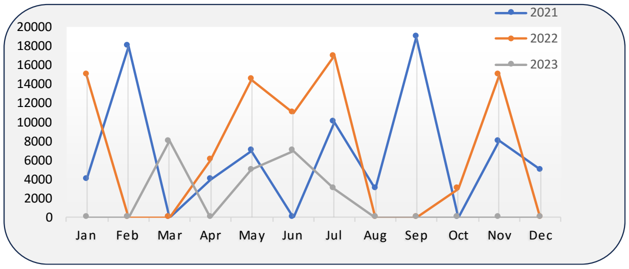


**Figure 1b: Trend of Maintenance Technician's Labour cost**

Figure 1a shows that June 2022 recorded the highest number of times, 3, the machine was maintained while figure 1b shows that in September 2021 the Technician was paid N19,000 which stands as the month with the peak payment. Maintenance in 2023 was quite bright as Figure 2 indicates that the average maintenance frequency stand at 0.71 against 1 and 0.92 recorded in 2021 and 2022 respectively. Also, the average cost of the Technician's labour stood at N3,285.71 for 2023 against the incurred average of N6,500 and N6,791.67 for 2021 and 2022

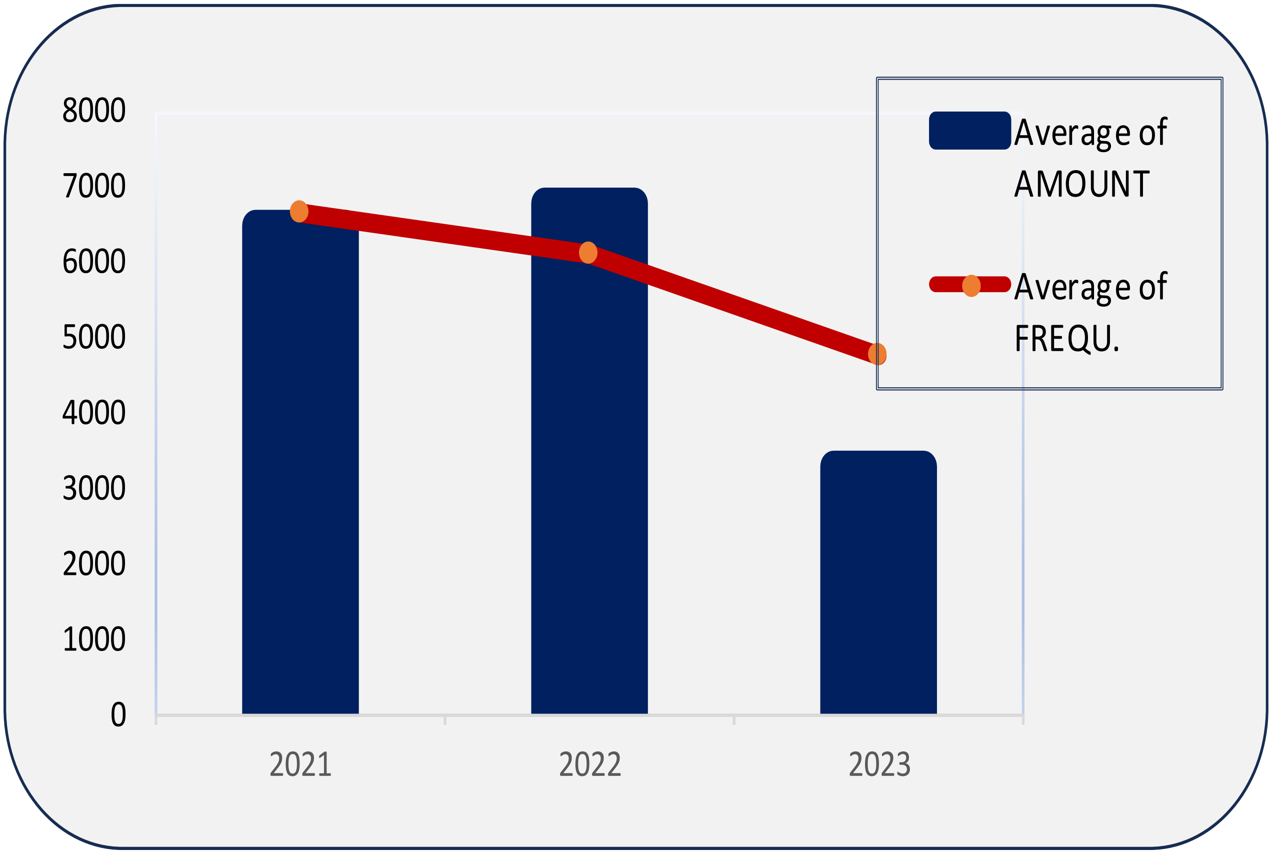


**Figure 2: Average Technician's cost and machine maintenance frequency**

The economic advantages linked to the technician's labor cost are illustrated in Figures 4a and 4b. Figure 4a delineates the mean monthly savings, showcasing the disparities when comparing 2023 with 2021 (N3,214.29), 2023 with 2022 (N3360), and the combined comparison of 2023 with 2021and 2022 (N3,505.95).

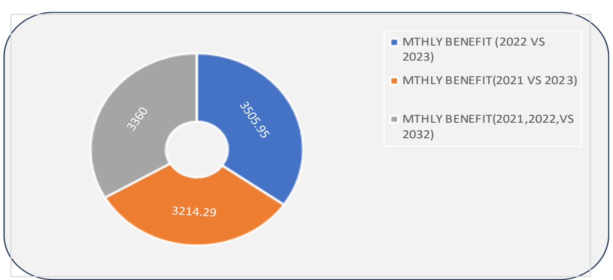


**Figure 4a: Comparative average Monthly Benefit on Technician's labor cost**

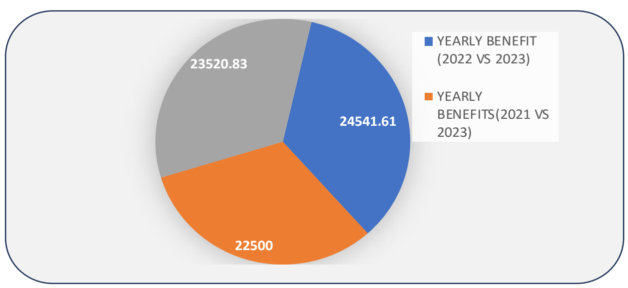


**Figure 4b: Comparative 7 months Benefit on Technician's labor cost**

Figure 4b shows what the benefit stands at the seventh month of 2023: 2023 to 2021 (N22,500), 2023 to 2022 (N24,541.61) and 2023 to 2021 and 2022 (N23,520.83).

## 4.2 Machine components replacement cost/benefit

Figure 5a and 5b show that the three times replacement of the printhead in 2022 attracted the highest cost in machine component at N510,000. This is seconded by replacing printhead twice in 2022 at a cost of N340,000

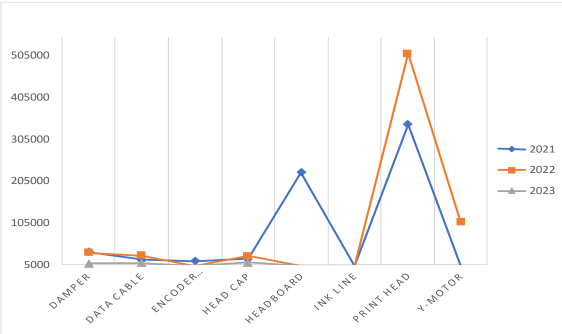


**Figure 5a: Replaced Machine components' cost Replacement**

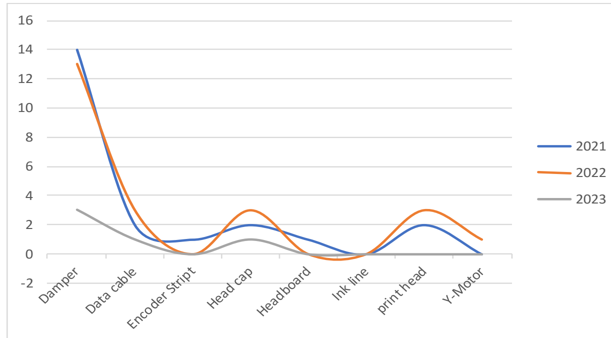


**Figure 5b: Frequency of Machine components'**

It is important to highlight that, often, the replacement of the printhead necessitates the replacement of associated components such as the data cable, head cap, and dampers. Consequently, the cost incurred when changing the printhead tends to exceed the cost of the printhead alone. Therefore, it becomes crucial to adopt strategies that minimize the frequent replacement of the printhead. The implementation of an IoT system in this context has proven effective in safeguarding the printhead from recurrent damages, resulting in a substantial reduction in the need for frequent replacement. This is evident in the data for 2023, where the average monthly cost for machine components replacement is remarkably low at N3,500. This is in stark contrast to the average monthly costs of N53,833.33 in 2021 and N58,208.33 in 2022, as illustrated in Figure 6. Notably, there were no replacements of the printhead or other costly machine components in 2023.

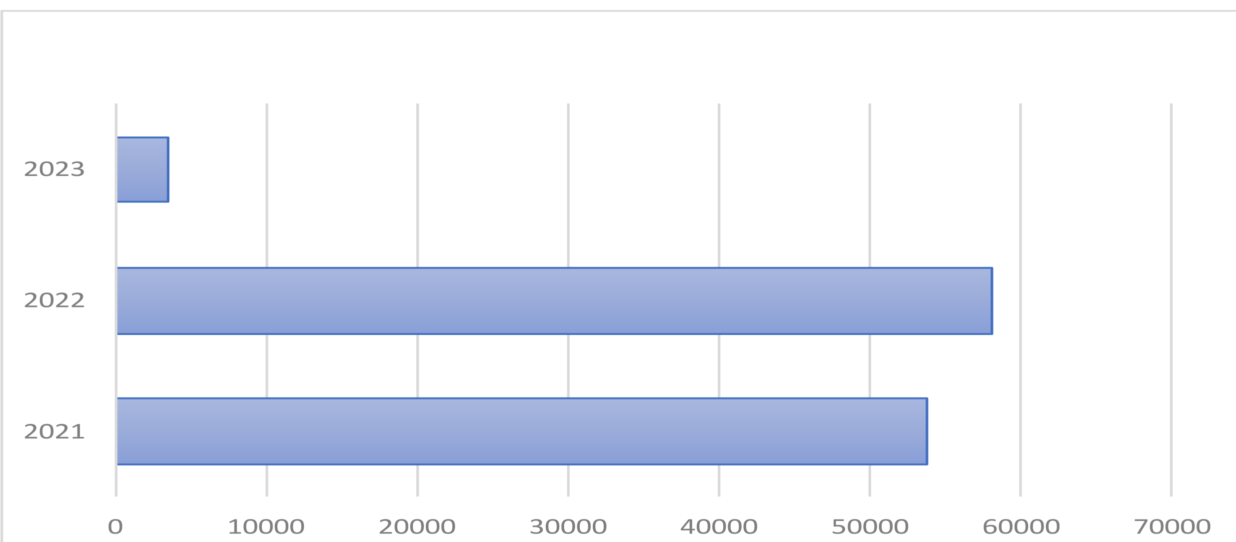


**Figure 6: Average monthly cost of Replaced Machine components**

The cost-benefit related to machine component replacement is elucidated in Figures 7 which shows the average monthly savings in 2023 compared to 2021 (N50,333.23), 2023 compared to 2022

(N54,708.33), and 2023 compared to the aggregate of 2021 and 2022 (N52,520.83). These figures underscore the financial advantages gained through the implementation of the discussed strategies.

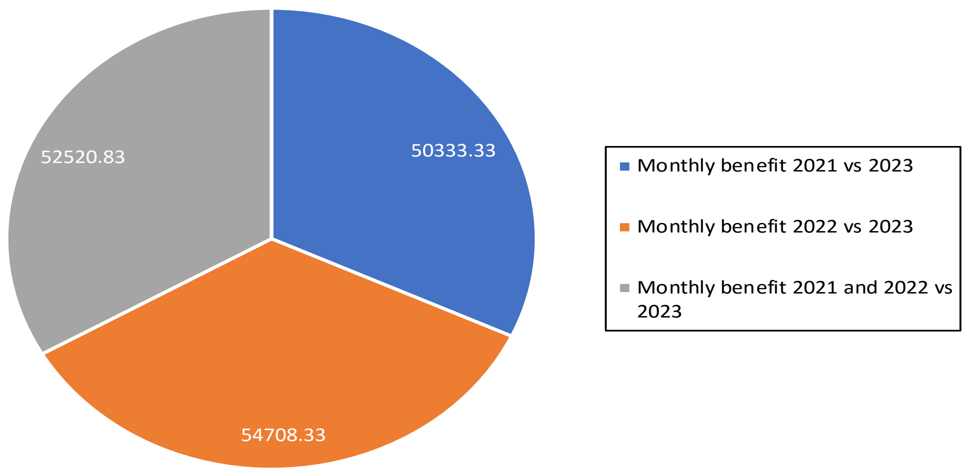


**Figure 7: Comparative average Monthly Benefit on Machine component replacement**

### 4.3 Consumables usage cost/benefit analysis

The Yinghe 6-feet large format printer employed in this study is utilized for the printing of flex banners crafted from polyvinyl chloride (PVC). Capable of printing up to a maximum width of 6 feet and accommodating varying lengths based on the media supplied, the key consumables for print production are the flex material and ink. This section provides an analysis of the cost/benefit implications associated with the utilization of flex (measured in $ft^2$) and ink (measured in L).

Figure 8a indicates that in the year 2023, despite achieving the highest average area of flex printing at 6124 $ft^2$, surpassing the 5854 $ft^2$ printed in 2021 and the 5794 $ft^2$ in 2022, there was a substantial reduction in wasted/unaccounted flex, amounting to 129 $ft^2$. This is noteworthy when compared to the 1042 $ft^2$ and 111 $ft^2$ of wasted flex recorded in 2021 and 2022, respectively. Consequently, this reduction had a significant impact on the cost of wasted flex, as illustrated in Figure 8b.

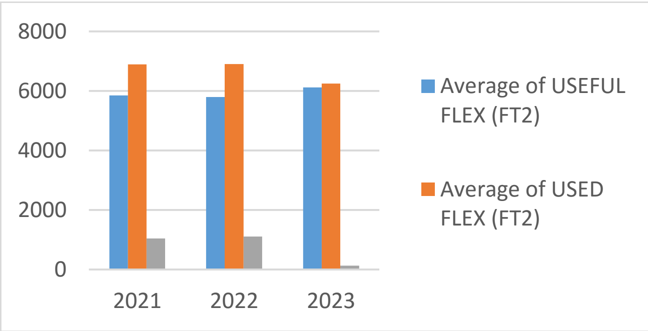


**Figure 8a: Average monthly usage of Flex**

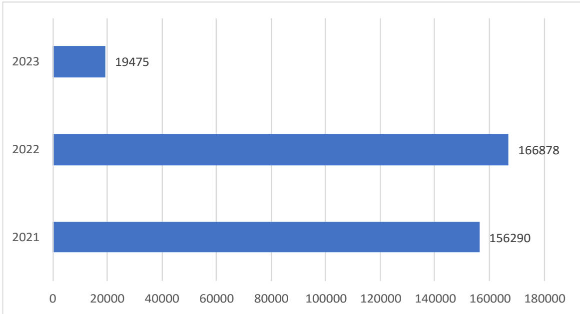


**Figure 8b: Average monthly cost of wasted/unaccounted Flex**

The substantial savings resulting from the reduction in wasted flex can be attributed to the heightened productivity facilitated by the IoT-based maintenance system. Additionally, the system's capability to meticulously track the jobs executed on the machine serves as an effective deterrent against any potential misappropriation or theft of flex materials. It is noteworthy to mention that such incidents of theft or misappropriation could have been more prevalent in 2021 and 2022 when the IoT system was not in use.

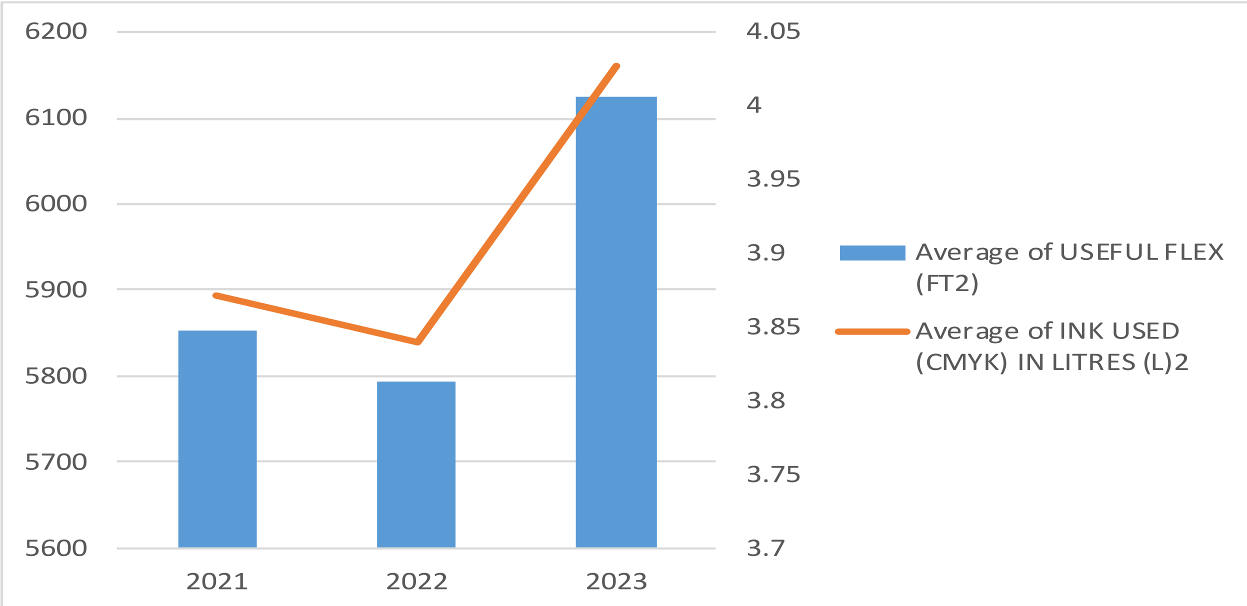


**Figure 9: Average useful Flex and Average Ink used**

Figure 9 illustrates that the highest monthly average ink consumption occurred in 2023, reaching 4.03 liters, compared to 3.87 liters and 3.84 liters in 2021 and 2022, respectively. This increased ink usage aligns with the higher volume of flex printed during that period. A more detailed analysis further indicates that, while a liter of ink in 2021 printed 1509.6 $ft^2$ of flex and 1509.7 $ft^2$ of flex in 2022, the same quantity of ink in 2023 was able to print 1,521 $ft^2$ of flex. This suggests an improvement in ink efficiency in 2023, despite the higher ink consumption, as it resulted in a greater area coverage of flex material

### 4.4 Research Findings, Applications, Recommendations, and Contribution to Knowledge

- In 2023, maintenance frequency reduced to an average of 0.71 times, with an average cost of N3285.71 representing 49.4% reduction in average monthly technician's labor cost.
- Monthly savings were significant, with N3505.95 when comparing 2023 to both 2021 and 2022.
- Printhead replacements in 2022 led to the highest cost at N510,000, with another significant cost at N340,000 for two replacements in 2021.
- The IoT system in 2023 resulted in a low average machine component replacement monthly cost of N3,500, compared to N53,833.33 in 2021 and N58,208.33 in 2022. This indicates a 93.9% reduction in average monthly cost of parts replacement. This may sound huge but very realistic. As highlighted in section 4.2, the major contributor to huge cost of part replacement is the printhead and has been guarded from excessive secondary failures by the IoT system.

- Despite printing the highest average area of flex in 2023 (6124 ft²), wasted/unaccounted flex reduced significantly to 129 ft², compared to 1042 ft² in 2021 and 111 ft² in 2022. This represents an 87.6% reduction in wasted/unaccounted flex.
- More ink efficiency was recorded in 2023, improved to 1,521 ft² of flex per liter.
- The findings have practical implications for industries relying on large-format printing machines (such as printing, advertising) firms) providing insights into the tangible s of IoT adoption. The applications extend to optimizing maintenance practices, reducing operational costs, and improving overall machine performance.
- This research contributes to the existing knowledge by providing empirical evidence of the economic advantages associated with IoT-driven maintenance in the context of large-format printing machinery. The study expands the understanding of how IoT technologies can be effectively utilized to optimize maintenance practices, reduce costs, and enhance overall operational performance in industrial settings.

## 5 Conclusion

In conclusion, the integration of an Internet of Things (IoT)-enhanced maintenance system for the Yinghe 6-feet large format printing machine has yielded transformative outcomes across multiple operational dimensions. The study reveals substantial benefits, including a significant reduction in maintenance frequency and associated labor costs, as well as a remarkable decrease in machine component replacement expenses, particularly for printheads. The implementation of the IoT system has proven instrumental in minimizing wasted flex material, leading to substantial cost savings. Also the system's efficiency improvement is evident, with a liter of ink covering a larger area of flex in 2023 compared to previous years.

The study assumes a consistent set of factors, including the skills of employees, the nature of the machine, the existing machine maintenance culture of the case organization, and the quality of replacement items, across both the pre-IoT and post-IoT periods.This assumption allows for a focused examination of the specific influence of IoT-driven strategies within the defined scope of the research. The duration of the study, coupled with this assumption, provides insights into the immediate and observable changes associated with the introduction of IoT applications. In essence, while the research establishes a correlation between IoT adoption and improved maintenance practices, the broader applicability of these findings should be interpreted in the context of the assumed constancy of certain influential variables

Overall, the findings underscore the cost-effectiveness of IoT adoption, positioning it as a pivotal tool for enhancing operational efficiency, reducing costs, and extending the lifespan of large-format printing machinery. This research provides valuable insights for industry practitioners considering the implementation of IoT technologies in large-format printing maintenance practices. . Future research endeavors could explore the dynamic nature of the assumed constant factors to provide a more comprehensive understanding of the long-term implications of IoT-driven maintenance strategies in industrial settings. Such attempts should also consider a wider range of data for more statistical generalization.

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# APENDIX 1

**MACHINE COMPONENT REPLACEMENT COST**

**2021**

| | DAMPERS | | PRINTHEAD | | Y-MOTOR | | INK LINE | | HEAD CAP | | DATA CABLE | | ENCODER STRIPT | | HEAD BOARD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MONTH** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** |
| JAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 6 | 15000 | 1 | 170000 | 0 | 0 | 0 | 0 | 1 | 9000 | 1 | 8000 | 0 | 0 | 0 | 0 |
| MARCH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| APRIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 2 | 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUNE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JULY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 12000 | 0 | 0 |
| AUG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEPT | 6 | 15000 | 1 | 170,000 | 0 | 0 | 0 | 0 | 1 | 9000 | 1 | 8000 | 0 | 0 | 0 | 0 |
| OCT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 225000 |
| DEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **14** | **35,000** | **2** | **340,000** | **0** | **0** | **0** | **0** | **2** | **18,000** | **2** | **16,000** | **1** | **12000** | **1** | **225000** |

**611,000**

**2022**

| | DAMPERS | | PRINTHEAD | | Y-MOTOR | | INK LINE | | HEAD CAP | | DATA CABLE | | ENCODER STRIPT | | HEAD BOARD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MONTH** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** | **QTY** | **COST** |
| JAN | 6 | 15,000 | 1 | 170,000 | 0 | 0 | 0 | 0 | 1 | 9,000 | 1 | 8,000 | 0 | 0 | 0 | 0 |
| FEB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MARCH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| APRIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 0 | 0 | 0 | 0 | 1 | 105,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUNE | 2 | 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JULY | 3 | 7500 | 1 | 170,000 | 0 | 0 | 0 | 0 | 1 | 9,000 | 1 | 8000 | 0 | 0 | 0 | 0 |
| AUG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEPT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOV | 2 | 5000 | 1 | 170000 | 0 | 0 | 0 | 0 | 1 | 9000 | 1 | 8000 | 0 | 0 | 0 | 0 |
| DEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **13** | **32,500** | **3** | **510,000** | **1** | **105000** | **0** | **0** | **3** | **27,000** | **3** | **24,000** | **0** | **0** | **0** | **0** |

666,000

**2023**

| | DAMPERS | | PRINTHEAD | | Y-MOTOR | | INK LINE | | HEAD CAP | | DATA CABLE | | ENCODER STRIPT | | HEAD BOARD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | QTY | COST | QTY | COST | QTY | COST | QTY | COST | QTY | COST | QTY | COST | QTY | COST | QTY | COST |
| JAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MARCH | 2 | 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| APRIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9,000 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUNE | 1 | 2500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8000 | 0 | 0 | 0 | 0 |
| JULY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | **3** | **7,500** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **9,000** | **1** | **8,000** | **0** | **0** | **0** | **0** |

# APPENDIX 2

| MAINTENANCE TECHNICIAN'S LABOUR COST | | | | | | |
|---|---|---|---|---|---|---|
| | 2021 | | 2022 | | 2023 | |
| MONTH | FREQU. | AMOUNT | FREQU. | AMOUNT | FREQU. | AMOUNT |
| JAN | 1 | 4,000 | 1 | 15,000 | 0 | 0 |
| FEB | 2 | 18,000 | 0 | 0 | 0 | 0 |
| MARCH | 0 | 0 | 0 | 0 | 1 | 8000 |
| APRIL | 1 | 4,000 | 1 | 6,000 | 0 | 0 |
| MAY | 1 | 7,000 | 2 | 14,500 | 1 | 5000 |
| JUNE | 0 | 0 | 3 | 11,000 | 2 | 7000 |
| JULY | 1 | 10,000 | 2 | 17,000 | 1 | 3000 |
| AUG | 1 | 3,000 | 0 | 0 | | |
| SEPT | 2 | 19,000 | 0 | 0 | | |
| OCT | 0 | 0 | 1 | 3,000 | | |
| NOV | 2 | 8,000 | 1 | 15,000 | | |
| DEC | 1 | 5,000 | 0 | 0 | | |
| **TOTAL** | 12 | 78,000 | 11 | **81,500** | **5** | **23,000** |

# APENDIX 3

| PERIOD | USEFUL FLEX ($FT^2$) | USED FLEX ($FT^2$) | WASTED/UNACCOUNTED FLEX ($FT^2$) | COST OF WASTED FLEX AT N150 PER ($FT^2$) | INK USED (CMYK) IN LITRES (L) | COST OF INK USED (N) |
|---|---|---|---|---|---|---|
| Jan-21 | 4003.72 | 4716.38 | 712.66 | 106899.32 | 2.65 | 25155.65 |
| Feb-21 | 4972.44 | 5857.53 | 885.09 | 132764.15 | 3.29 | 31242.18 |
| Mar-21 | 6243.11 | 7354.38 | 1111.27 | 166691.04 | 4.13 | 39225.89 |
| Apr-21 | 4302.09 | 5067.86 | 765.77 | 114865.80 | 2.85 | 27030.33 |
| May-21 | 4621.34 | 5443.94 | 822.60 | 123389.78 | 3.06 | 29036.20 |
| Jun-21 | 4891.22 | 5761.86 | 870.64 | 130595.57 | 3.23 | 30731.87 |
| Jul-21 | 3904.85 | 4599.91 | 695.06 | 104259.50 | 2.58 | 24534.44 |
| Aug-21 | 5849.5 | 6890.71 | 1041.21 | 156181.65 | 3.87 | 36752.81 |
| Sep-21 | 6901.98 | 8130.53 | 1228.55 | 184282.87 | 4.56 | 43365.62 |
| Oct-21 | 5732.04 | 6752.34 | 1020.30 | 153045.47 | 3.79 | 36014.80 |
| Nov-21 | 9844 | 11596.23 | 1752.23 | 262834.80 | 6.51 | 61850.53 |
| Dec-21 | 8976.56 | 10574.39 | 1597.83 | 239674.15 | 5.94 | 56400.34 |
| Jan-22 | 3947.5 | 4705.42 | 757.92 | 113688.00 | 2.62 | 24851.72 |
| Feb-22 | 5493 | 6547.66 | 1054.66 | 158198.40 | 3.64 | 34581.51 |
| Mar-22 | 7937.25 | 9461.20 | 1523.95 | 228592.80 | 5.26 | 49969.43 |
| Apr-22 | 4992.75 | 5951.36 | 958.61 | 143791.20 | 3.31 | 31432.16 |
| May-22 | 3326.25 | 3964.89 | 638.64 | 95796.00 | 2.20 | 20940.61 |
| Jun-22 | 4508.75 | 5374.43 | 865.68 | 129852.00 | 2.99 | 28385.11 |
| Jul-22 | 4273 | 5093.42 | 820.42 | 123062.40 | 2.83 | 26900.93 |
| Aug-22 | 5523 | 6583.42 | 1060.42 | 159062.40 | 3.66 | 34770.38 |
| Sep-22 | 5134.25 | 6120.03 | 985.78 | 147866.40 | 3.40 | 32322.98 |
| Oct-22 | 5209.5 | 6209.72 | 1000.22 | 150033.60 | 3.45 | 32796.72 |
| Nov-22 | 11723.75 | 13974.71 | 2250.96 | 337644.00 | 7.77 | 73807.57 |
| Dec-22 | 7463.52 | 8896.52 | 1433.00 | 214949.38 | 4.95 | 46987.04 |
| Jan-23 | 11358.75 | 11599.56 | 240.81 | 36120.83 | 7.47 | 70945.51 |
| Feb-23 | 5637.5 | 5757.02 | 119.52 | 17927.25 | 3.71 | 35211.21 |
| Mar-23 | 3958.25 | 4042.16 | 83.91 | 12587.24 | 2.60 | 24722.80 |
| Apr-23 | 5887.5 | 6012.32 | 124.82 | 18722.25 | 3.87 | 36772.68 |
| May-23 | 5438.75 | 5554.05 | 115.30 | 17295.23 | 3.58 | 33969.84 |
| Jun-23 | 5857.5 | 5981.68 | 124.18 | 18626.85 | 3.85 | 36585.31 |
| Jul-23 | 4731.25 | 4831.55 | 100.30 | 15045.38 | 3.11 | 29550.87 |