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IoT applications in asset management: A review of accounting and tracking techniques

Lawrence Damilare Oyeniyi [1,*], Chinonye Esther Ugochukwu [2] and Noluthando Zamanjomane Mhlongo [3]

[1] *Barclays Bank, United Kingdom*
[2] *Independent Researcher, Lagos, Nigeria*
[3] *City Power, Johannesburg, South Africa*

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Abstract

In the digital age, the confluence of Internet of Things (IoT) technologies with asset management practices heralds a transformative era, promising unprecedented efficiency and strategic advantage. This paper delves into the intricacies of this integration, exploring the evolution, challenges, and potential of IoT in reshaping asset management paradigms. With a keen aim to elucidate the transformative impact of IoT and navigate the complexities of its integration into asset management systems, the study adopts a qualitative research methodology, underpinned by a systematic literature review. This approach enables a comprehensive exploration of the subject matter, ensuring a nuanced understanding of the IoT's potential and pitfalls within the asset management domain.

The findings illuminate a landscape where IoT applications significantly enhance asset utilization rates, underscored by empirical success stories and quantifiable improvements in operational efficiency. However, the journey reveals barriers—technical, organizational, and cultural—that impede seamless IoT adoption. Addressing these challenges, the paper offers strategic recommendations, emphasizing the need for strategic alignment, inter-organisational collaboration, and robust data management strategies to overcome integration hurdles.

Conclusively, the study not only achieves its aim of highlighting the potential of IoT in asset management but also charts a course for future endeavors in this field. It posits that the strategic integration of IoT technologies stands as a cornerstone for the next generation of asset management practices, promising a future marked by enhanced efficiency, economic viability, and strategic agility. The recommendations provided serve as a compass for organizations embarking on the IoT integration journey, guiding them towards a horizon of transformative potential.

Keywords: Internet of Things; Asset Management; Integration Challenges; Operational Efficiency; Strategic Recommendations; Systematic Literature Review.

1. Introduction

1.1. Introduction to Asset Management in the Digital Age

Asset management, a critical component of organizational strategy, has undergone a significant transformation in the digital age. The integration of digital technologies, particularly the Internet of Things (IoT), has revolutionized how assets are monitored, maintained, and optimized across various sectors. This evolution is not merely a trend but a fundamental shift in how businesses approach the lifecycle management of their assets, from acquisition to disposal (Ye et al., 2023).

* Corresponding author: Lawrence Damilare Oyeniyi

The digital age has ushered in an era where the traditional boundaries of asset management are expanded through digital technologies, enabling a more integrated, efficient, and proactive approach. The advent of IoT technologies has been particularly transformative, offering unprecedented visibility and control over assets in real-time (Selvakumar et al., 2023). This shift is not without its challenges, however, as organizations strive to integrate these new technologies into their existing asset management frameworks.

One of the key benefits of digitalization in asset management is the ability to enhance asset condition assessment, leading to better-informed decision-making and, ultimately, more effective asset management (Ye et al., 2023). The integration of AIM (Asset Information Model), IoT, and blockchain technologies has shown to significantly influence asset condition assessments, improving asset monitoring, diagnostics, and cross-functional collaboration (Ye et al., 2023).

The application of IoT sensors in asset management exemplifies the practical implications of digital technologies. These sensors provide real-time data on asset conditions, usage, and performance, enabling organizations to optimize asset utilization, reduce downtime, and extend equipment lifespans (Selvakumar et al., 2023). The potential of IoT in asset management is vast, offering opportunities to streamline supply chains, reduce costs, and enhance customer satisfaction.

The digital transformation of asset management represents a paradigm shift towards more dynamic, data-driven approaches. The integration of digital technologies, particularly IoT, into asset management processes offers significant benefits, including improved asset utilization, enhanced decision-making capabilities, and increased operational efficiencies. However, the successful adoption of these technologies requires overcoming integration challenges and addressing security and regulatory considerations. As organizations continue to navigate the complexities of the digital age, the role of digital technologies in asset management will undoubtedly continue to evolve and expand.

1.2. Evolution of IoT Technologies in Business Processes

The evolution of Internet of Things (IoT) technologies has been a cornerstone in the digital transformation of business processes, marking a significant shift from traditional operations to data-driven decision-making and automation. This transformation is evident across various sectors, with the banking, financial services, and insurance (BFSI) sector emerging as a prime example of IoT's potential to revolutionize business models (Gupta & Kulkarni, 2023). The integration of IoT devices in the BFSI sector has enabled the collection, sharing, and analysis of data from internet-connected devices, leading to improved efficiency, enhanced customer loyalty, and the anticipation of customer needs (Gupta & Kulkarni, 2023).

The digital transformation facilitated by IoT extends beyond the BFSI sector, influencing a wide range of industries by enabling smart infrastructure and supporting the development of agile services and connected products. The adoption of IoT technologies fosters the creation of flexible and adaptable ecosystems, where business services and distributed information systems can thrive in a digitally transformed environment (Zimmermann et al., 2016). This adaptability is crucial for businesses aiming to maintain competitiveness and innovation in the digital age.

The multi-perspective digitization architecture proposed by Zimmermann et al. (2016) offers a framework for integrating IoT within enterprise architectures, facilitating the transition towards digital enterprises. This approach emphasizes the importance of flexibility and agility in business transformation, enabling organizations to adapt to the rapidly evolving digital landscape.

The evolution of IoT technologies has played a pivotal role in the digital transformation of business processes, offering opportunities for innovation, efficiency, and sustainability. The integration of IoT into various sectors, including BFSI, healthcare, and manufacturing, demonstrates the technology's versatility and its potential to drive significant improvements in operational performance and customer engagement. As businesses continue to explore the possibilities offered by IoT, the challenges related to legal regulations, data security, and system interoperability will require careful consideration and strategic planning.

1.3. Accounting Techniques in Asset Management

The integration of accounting techniques in asset management has evolved significantly with the advent of digital technologies, particularly through the implementation of Management Information Systems and Accounting for State Property (SIMAK-BMN). This evolution reflects a transition from traditional asset management practices to more sophisticated, data-driven approaches that leverage technology for enhanced accuracy and efficiency (Sarif, Ridwan, & Kasim, 2022; Apriliyana, Palikhatun, & Payamta, 2019).

At the core of this transformation is the application of basic accounting concepts to the administration of state property, as demonstrated in the case of the Palu Religious High Court Regional Coordinator. The study by Sarif, Ridwan, and Kasim (2022) highlights the challenges of asset registration, recording, and reporting in the absence of a unified, technology-driven system. The adoption of SIMAK-BMN aims to address these challenges by ensuring that asset management processes are supported by valid source documents and that data and information on state property are updated regularly.

The implementation of SIMAK-BMN within the Public Service Agency (BLU) of Universitas Sebelas Maret Surakarta further illustrates the benefits of integrating management information systems and accounting in asset management. Apriliyana et al. (2019) identify the advantages of this approach, including improved control over asset management and enhanced understanding of asset management regulations among stakeholders. However, the study also acknowledges the existence of implementation challenges, such as incomplete stakeholder understanding of BMN management rules and a focus on procurement to the detriment of other management aspects.

The advent of Industry 4.0 has introduced new asset categories, including physical, virtual, and human assets, and has emphasized the importance of innovative tracking techniques, such as RFID tags, QR codes, and LoRa tags, facilitated by the Industrial Internet of Things (IIoT). These technologies enhance information visibility and process automation, enabling more effective asset management practices (Teoh, Gill, & Parlikad, 2021).

Predictive maintenance models, powered by IoT and fog computing, represent a significant advancement in asset management. These models utilize machine learning to predict equipment failure, allowing for timely decision-making regarding repairs or replacements. Teoh, Gill, and Parlikad (2021) demonstrate that such models can significantly improve execution time, reduce costs, and lower energy usage, thereby enhancing overall asset management efficiency.

Furthermore, the review by Aminifar et al. (2021) on power system protection and asset management underscores the potential of machine learning techniques to revolutionize asset management. By facilitating predictive maintenance and optimizing task distributions, these technologies offer a pathway to more resilient and efficient asset management systems.

The integration of accounting techniques and digital technologies in asset management has led to significant improvements in the accuracy, efficiency, and effectiveness of asset management practices. The adoption of systems like SIMAK-BMN and the application of machine learning for predictive maintenance are indicative of the ongoing evolution of asset management in the digital age. As these technologies continue to develop, they promise to further enhance the capability of organizations to manage their assets in a more informed and strategic manner.

1.3.1. Tracking Techniques: From Barcodes to IoT Solutions

Eneh et al. (2022) highlight the critical role of IoT technologies, such as barcodes, Radio Frequency Identifications (RFIDs), Global Positioning System (GPS) asset tracking, and Near Field Communication (NFC) in optimizing the use of medical equipment. This technological advancement not only facilitates the efficient location and utilization of equipment but also significantly impacts healthcare delivery by reducing equipment downtime and enhancing patient care.

Khalid and Ejaz (2022) discuss the application of IoT in rental asset tracking and monitoring, presenting an on-demand system that utilizes various wireless technologies, including WiFi, Bluetooth, GSM cellular, and LoRa. This system addresses the challenges of managing rental assets by providing business owners with the ability to track the physical location of items, thereby improving asset utilization and reducing the risk of loss or theft.

These advancements in tracking technologies underscore the transformative potential of IoT solutions in asset management. By moving beyond traditional barcodes to more sophisticated IoT systems, organizations can achieve greater operational efficiency, enhanced security, and improved decision-making capabilities. The integration of IoT with other technologies, such as blockchain, further enhances the reliability and transparency of tracking systems, making them indispensable tools in the digital age.

The evolution from barcodes to IoT solutions in tracking techniques marks a significant milestone in the field of asset management. This transition has enabled industries to overcome previous limitations and unlock new possibilities for managing and optimizing assets. As IoT technologies continue to evolve and integrate with other innovative solutions, the future of asset tracking and management looks increasingly efficient, secure, and data-driven.

1.4. Integration Challenges of IoT in Existing Asset Management Systems

Karthikamani et al. (2023) illustrate the potential of integrating IoT with machine learning for asset tracking and management. Their study on RFID-enabled IoT asset management systems underscores the technical challenges involved in achieving high accuracy and efficiency in asset tracking. The integration of machine learning algorithms, such as Gradient Boosting and Random Forest, with IoT technologies, demonstrates the complexity of developing systems that are both accurate and reliable.

Altohami, Haron, and Law (2021) delve into the integration challenges of combining Building Information Modeling (BIM), IoT, and facility management for renovating existing buildings. Their review highlights the difficulties in merging static models with real-time data from IoT devices, emphasizing the need for smart methodologies and the adoption of Service-Oriented Architecture (SOA) to facilitate seamless integration. This approach aims to address interoperability issues and enhance construction and operational efficiencies.

Al Sadawi, Hassan, and Ndiaye (2021) explore the role of blockchain technology in overcoming some of the inherent challenges in IoT networks, such as security, authenticity, reliability, and scalability. Their survey on the integration of blockchain with IoT to enhance performance and eliminate challenges sheds light on the potential of blockchain to provide a decentralized, secure, and transparent framework for IoT systems. This integration is crucial for addressing the security and privacy vulnerabilities that plague IoT implementations.

Arshad et al. (2023) focus on the application of blockchain technology for decentralized trust management in IoT. They identify the requirements and challenges of developing blockchain-based trust management systems for various IoT applications, including the Internet of Medical Things (IoMT), Internet of Vehicles (IoV), Industrial IoT (IIoT), and Social IoT (SIoT). The study emphasizes the importance of trust management in ensuring secure and reliable exchanges of information within IoT systems, highlighting the complexities involved in integrating blockchain technology to enhance security and trust.

The integration of IoT technologies into existing asset management systems represents a significant shift towards more dynamic, data-driven asset management practices. While the challenges are considerable, the potential benefits in terms of efficiency, accuracy, and security are compelling. Organizations that successfully navigate these integration challenges can expect to achieve significant competitive advantages in an increasingly digitalized business environment.

1.5. Regulatory and Security Considerations in IoT Deployments

Minoli, Sohraby, and Occhiogrosso (2017) highlight the transformative potential of IoT in smart buildings, emphasizing the critical role of energy optimization and building management systems. However, they also point out the deployment-limiting issues such as fragmented cybersecurity solutions and the lack of comprehensive end-to-end standards. These challenges underscore the importance of establishing robust security frameworks and standards to protect IoT systems from vulnerabilities and ensure their safe integration into existing infrastructures.

Ventulett and Villegas (2018) discuss the specific challenges faced by the oil and gas industry in adopting IoT technologies, particularly in hazardous environments where regulatory restrictions for combustible atmospheres are stringent. The paper illustrates the necessity of "intrinsically safe" devices that are designed to prevent ignition in explosive environments, highlighting the regulatory hurdles that must be overcome to leverage IoT's benefits in such critical industries.

Organizations embarking on IoT deployments must navigate a complex regulatory environment that varies by industry and geography. Compliance with data protection laws, such as the General Data Protection Regulation (GDPR) in Europe, and industry-specific standards, such as the Health Insurance Portability and Accountability Act (HIPAA) in healthcare, is crucial. Moreover, the development and implementation of IoT solutions must incorporate security-by-design principles to address vulnerabilities and protect against cyber threats.

The deployment of IoT technologies in asset management and other applications presents a myriad of regulatory and security challenges that organizations must address. Ensuring compliance with regulatory standards and implementing comprehensive security measures are critical for the successful and safe integration of IoT systems. As IoT continues to evolve, ongoing collaboration between industry stakeholders, regulatory bodies, and technology providers will be essential to navigate the complex landscape of IoT deployments.

1.6. Potential of IoT to Transform Asset Management Efficiency

Selvakumar et al. (2023) delve into the realm of smart asset management, illustrating how IoT sensors can significantly enhance the tracking and optimization of assets. Their research underscores the ability of IoT to provide real-time information on the whereabouts, conditions, and usage of assets, thereby streamlining processes, preventing issues, and saving costs. The integration of machine learning algorithms further amplifies the accuracy and efficiency of asset management, marking a significant leap from traditional methods.

Hasan and Habib (2022) focus on the impact of IoT on supply chain management (SCM), highlighting how IoT innovations foster efficiency, visibility, and transparency. The interconnectedness facilitated by IoT devices allows for seamless data exchange, enhancing SCM operations and enabling proactive decision-making. This level of integration exemplifies the broader applicability of IoT in transforming asset management practices across sectors.

Patil and Bhaumik (2023) investigate the efficiency of IoT-enabled systems in reducing construction costs. Their study identifies key cost-contributing factors in construction and demonstrates how IoT applications, such as mobile computing technology, unmanned aerial vehicles (UAVs), sensor technology, and RFID technology, can mitigate these costs. The findings reveal the substantial potential of IoT to improve site management, safety management, and overall construction management efficiency.

Karthikamani et al. (2023) present an RFID-enabled IoT asset management system integrated with machine learning, offering a solution to the inefficiencies and inaccuracies of traditional asset tracking methods. Their system not only tracks assets with improved precision but also employs machine learning to enhance data processing, showcasing the synergistic potential of IoT and artificial intelligence (AI) in asset management.

In the construction industry, the application of IoT technologies promises to overcome traditional challenges of cost overruns and project delays. Through enhanced data collection and analysis, IoT-enabled systems provide actionable insights that drive cost savings and ensure timely project completion.

The potential of IoT to transform asset management efficiency is vast and multifaceted. From improving supply chain operations to reducing construction costs and beyond, IoT technologies offer unprecedented opportunities for optimization and innovation. As organizations continue to explore and adopt IoT solutions, the future of asset management looks increasingly efficient, responsive, and data-driven.

1.6.1. The Significance of IoT in Enhancing Asset Visibility

Sarkar, Patel, and Dave (2020) discuss the development of an integrated cloud-based IoT platform for the asset management of elevated metro rail projects. This platform provides real-time information about various assets and their locations, which is crucial for better management. The implementation of this platform demonstrates a substantial improvement in production efficiency, with reductions in paperwork and cycle times for casting and transportation of precast segments. This case study exemplifies how IoT enhances asset visibility, leading to more efficient asset management practices.

Sidhu et al. (2020) focus on automating switchgear asset supply chain management using IoT and RFID technology. Their research highlights the challenges faced in traditional supply chain management, such as delays and misrouted assets, and proposes an IoT-based solution to overcome these issues. By enabling real-time monitoring of assets as they travel along global transportation routes, IoT technologies significantly reduce losses and improve the efficiency of supply chain management. This study underscores the importance of IoT in achieving greater transparency and visibility in asset management.

Teoh, Gill, and Parlikad (2021) present an IoT and fog-computing-based predictive maintenance model for effective asset management in Industry 4.0. Their model utilizes machine learning to predict equipment failure, allowing for timely decision-making regarding repairs or replacements. This approach not only enhances asset visibility but also contributes to reduced downtime and lower maintenance costs. The integration of IoT with predictive analytics exemplifies the potential of IoT technologies to transform asset management by providing actionable insights into asset conditions.

The significance of IoT in enhancing asset visibility extends beyond tracking and maintenance. It encompasses the entire lifecycle of assets, from procurement to disposal, enabling organizations to optimize asset utilization and extend their lifespan. By providing a comprehensive view of asset performance and usage patterns, IoT technologies facilitate informed decision-making and strategic planning.

The significance of IoT in enhancing asset visibility cannot be overstated. By enabling real-time tracking, predictive maintenance, and strategic asset optimization, IoT technologies transform asset management practices. As organizations continue to adopt IoT solutions, the potential for further innovation and efficiency gains in asset management remains vast.

1.7. Aims, Objectives, and Scope of the Study

This study aims to explore the transformative impact of Internet of Things (IoT) technologies on asset management processes, with a focus on enhancing efficiency, visibility, and strategic decision-making. The first objective is to assess how IoT technologies can improve asset utilization rates and reduce operational costs by enabling real-time tracking and monitoring of assets. This involves evaluating the effectiveness of IoT solutions in providing actionable insights that facilitate proactive maintenance and optimize asset life cycles. The second objective is to examine the integration challenges of IoT technologies within existing asset management systems, identifying technical, regulatory, and security barriers and proposing strategies to overcome these obstacles. This includes an analysis of the interoperability of IoT devices and platforms, as well as the development of comprehensive frameworks that ensure data privacy and security compliance. The third objective is to investigate the potential of IoT to enhance asset visibility across various industries, thereby supporting better inventory management, reducing asset loss, and improving supply chain transparency. This will involve case studies and empirical research to demonstrate the practical applications and benefits of IoT in asset management. The scope of this study encompasses a wide range of industries where asset management plays a critical role, including manufacturing, construction, logistics, and utilities, providing a holistic view of the potential and challenges of implementing IoT solutions in asset management practices.

2. Methodology of the Study

2.1. Qualitative Research Approach and Systematic Literature Review Process for Understanding IoT's Impact on Asset Management

The qualitative research approach is instrumental in exploring the multifaceted impact of Internet of Things (IoT) technologies on asset management. This approach allows for an in-depth understanding of the nuances and complexities involved in integrating IoT into asset management systems. The adoption of IoT technologies in asset management brings forth a plethora of opportunities for innovation and efficiency improvements. However, it also introduces significant challenges, particularly in the realms of cybersecurity and system integration (Okporokpo et al., 2023). The qualitative research methodology, through systematic literature reviews and case studies, provides a comprehensive overview of these opportunities and challenges.

A systematic literature review, as demonstrated by Chweya and Ibrahim (2021), offers a structured method for identifying, evaluating, and synthesizing the existing body of research on IoT implementations in various domains. This approach is particularly beneficial for understanding the application areas, benefits, and challenges of IoT in asset management. By focusing on qualitative studies, researchers can delve into the experiences and perceptions of stakeholders involved in IoT deployments, offering insights into the practical aspects of technology adoption and integration.

The significance of trust-based approaches in enhancing IoT security highlights the importance of qualitative research in identifying and categorizing the various strategies to mitigate cybersecurity threats inherent in IoT systems (Okporokpo et al., 2023). These insights are crucial for asset management, where the security and integrity of data are paramount. Furthermore, the exploration of TCP performance enhancement in IoT and MANET networks through a systematic literature review sheds light on the technical challenges and solutions relevant to the reliable performance of IoT devices in asset management scenarios (Parween & Hussain, 2023).

The systematic literature review process is a critical component of the qualitative research approach, enabling researchers to construct a comprehensive and unbiased understanding of the current state of knowledge on IoT's impact on asset management. This process involves a meticulous search of databases to gather relevant literature, followed by a rigorous evaluation of the studies based on predefined inclusion and exclusion criteria. The review conducted by Hussain et al. (2022) exemplifies the meticulous process of identifying and analyzing literature on lightweight authentication algorithms for IoT, underscoring the importance of systematic reviews in uncovering trends, gaps, and future research directions in the context of IoT security.

The qualitative research approach, supported by systematic literature reviews, offers a robust framework for investigating the multifaceted impact of IoT on asset management. Through this approach, researchers can uncover the

nuanced dynamics of technology adoption, the challenges of cybersecurity, and the strategies for enhancing system performance and security, thereby contributing to the development of effective and efficient asset management systems in the digital age.

3. Results of the Study

3.1. Improved Asset Utilization Rates through IoT Applications

The integration of Internet of Things (IoT) technologies into asset management has significantly improved asset utilization rates, marking a pivotal shift in how businesses monitor, control, and optimize their assets. Selvakumar et al. (2023) highlight the transformative potential of IoT sensors in providing real-time information on the condition, location, and usage of assets. This real-time data acquisition facilitates the optimization of asset usage, thereby enhancing productivity and reducing operational costs. The application of IoT sensors in factories, warehouses, and distribution centers has been particularly noted for its ability to monitor machinery performance, identify potential issues before they escalate, and streamline supply chain operations (Selvakumar et al., 2023).

Sarkar, Patel, and Dave (2020) demonstrate the practical application of IoT in managing assets for elevated metro rail projects through a cloud-based IoT platform. This platform not only improved real-time visibility of assets but also significantly reduced paperwork and cycle times for casting and transportation of precast segments by 30% and 50%, respectively. Such improvements underscore the efficiency gains achievable with IoT in asset management, particularly in complex project environments (Sarkar, Patel & Dave, 2020).

Lowenstein and Slater (2018) discuss the broader implications of IoT and real-time data in the context of Industry 4.0, emphasizing increased asset utilization, uptime, and operational flexibility. The adoption of IoT technologies enables organizations to move beyond traditional barriers, facilitating a seamless flow of real-time actionable data across different phases of a product's lifecycle. This integration leads to dramatic cost reductions and improvements in system accuracy, asset reuse, and overall business outcomes (Lowenstein & Slater, 2018).

Teoh, Gill, and Parlikad (2021) further explore the role of IoT and fog computing in predictive maintenance, an application of IoT that exemplifies the shift towards proactive asset management. By leveraging machine learning algorithms, their model predicts equipment failures, enabling timely decisions on repairs or replacements before failures disrupt production. This approach not only optimizes asset management tasks but also significantly reduces execution time, costs, and energy usage, demonstrating the effectiveness of IoT in enhancing asset utilization rates (Teoh, Gill, & Parlikad, 2021).

The collective insights from these studies illustrate the profound impact of IoT on asset management. By enabling real-time tracking, predictive maintenance, and operational optimization, IoT technologies have paved the way for unprecedented improvements in asset utilization rates. These advancements not only contribute to the operational efficiency and cost-effectiveness of businesses but also enhance the reliability and lifespan of assets. The integration of IoT into asset management practices represents a forward-thinking approach to leveraging technology for sustainable business growth and competitiveness.

3.1.1. Quantifying Improvements in Asset Utilization

Gavatiuk and Pilat (2022) discuss the improvement of current asset management mechanisms as a vital component for the effective functioning of enterprises. Their analysis suggests that a purposeful activity related to determining the amount, risk, and control over the formation and use of current assets is essential. By improving the mechanism of current asset management, enterprises can ensure optimal volumes of current assets, maintain necessary liquidity levels, and achieve a desirable level of profitability and risk management, thereby enhancing overall asset utilization (Gavatiuk & Pilat, 2022).

Ye et al. (2023) investigate the influence of integrating digital technologies, such as asset information models (AIM), IoT, and blockchain, on asset condition assessment and management. Their research highlights the strong impact of these technologies on improving asset monitoring and diagnostics throughout their lifecycle. The integration of AIM, IoT, and blockchain enhances cross-functional collaboration, reduces costs and risks, and increases performance during asset condition assessments, contributing to better asset management practices (Ye et al., 2023).

By adopting standardized methodologies, integrating advanced digital tools, and focusing on effective asset management mechanisms, organizations can achieve substantial improvements in operational efficiency, cost

reduction, and overall profitability. The quantification of these improvements provides a clear indication of the value that IoT technologies bring to asset management, highlighting their role as a critical driver for business strategy and a center for profitability.

3.2. Case Studies: Success Stories of IoT in Asset Management

The integration of Internet of Things (IoT) technologies into asset management has been transformative, offering unprecedented visibility, efficiency, and control over assets in various sectors. Through the lens of several case studies, the impact of IoT on asset management is both profound and multifaceted, demonstrating significant advancements in operational efficiency, cost reduction, and decision-making processes.

Brous et al. (2017) explore the adoption of IoT for data-driven decision-making in asset management organizations, highlighting the potential of IoT to automate and enhance the decision-making process. Their research, grounded in systematic literature review and case studies, underscores the low current level of IoT adoption despite its benefits. The study identifies the complexity of adopting a data-driven approach and the necessity of an effective data governance strategy to integrate IoT data into decision-making processes effectively.

In the realm of facilities management, Ali et al. (2021) present a compelling case study on Al Nabooda Chulia Facilities Management Co LLC, showcasing the integration of IoT, big data analytics, and mobile applications. This integration has led to significant reductions in management costs while improving facilities' performance and service quality. The case study exemplifies how digital transformation, through the adoption of IoT and related technologies, can optimize and innovate current practices, shifting the focus from cost management to value creation (Ali et al., 2021).

Further emphasizing the transformative impact of IoT, Brous, Janssen, and Herder (2018) analyze how IoT adoption reconfigures decision-making processes in asset management, particularly within the water management domain. Their findings reveal that IoT can significantly alter business processes to accommodate the real-time nature of data, necessitating organizational, business process changes, and the development of new capabilities. This transformation underscores the need for data provenance, governance, and standardization to fully leverage IoT's potential in asset management (Brous, Janssen, & Herder, 2018).

Karthikamani et al. (2023) delve into the technical advancements brought about by IoT in asset tracking, proposing a smart asset tracking system that integrates IoT technology with RFID sensors and machine learning algorithms. This system not only improves accuracy and efficiency in asset management but also includes mechanisms for theft or misplacement alerts. The study demonstrates the practical applications and benefits of IoT in enhancing asset tracking and inventory management across various industries.

3.3. Cost Reduction Achievements in Asset Maintenance and Operations through IoT

Fernandez and Rada (2021) present a compelling case study on the application of IoT-based predictive maintenance within a university's operations and maintenance (O&M) project. By adopting a Six Sigma approach, the study demonstrates how IoT can eliminate a significant portion of asset failures, reduce unscheduled maintenance costs by 40%-70%, and decrease labor costs by 10%-25%. Furthermore, the implementation led to a maintenance cost reduction of 25%-30% and a return on investment (ROI) tenfold within five years, showcasing the substantial financial benefits of integrating IoT into asset management practices (Fernandez & Rada, 2021).

Vadi et al. (2021) explore the efficiency gains in inventory management through the deployment of a low-cost IoT-based Asset Tracking and Inventory Management System (ATIM). This system enhances supply chain management by improving the speed and accuracy of inventory tracking, leading to better customer experiences and reduced operational costs. The study highlights the transformative potential of IoT in streamlining warehouse operations and supply chain logistics, contributing to overall cost reductions (Vadi et al., 2021).

Teoh, Gill, and Parlikad (2021) delve into the application of IoT and fog computing for predictive maintenance in Industry 4.0. Their research introduces a machine learning-based predictive maintenance model that optimizes task distributions and reduces execution time, cost, and energy usage. The model demonstrates a significant improvement in asset management efficiency, with a 0.48% faster execution time, 5.43% lower cost, and 28.10% lower energy usage compared to traditional methods. This approach not only enhances operational efficiency but also contributes to substantial cost savings (Teoh, Gill, & Parlikad, 2021).

Bhanji et al. (2021) discuss the role of advanced Enterprise Asset Management (EAM) systems in leveraging IoT for predictive maintenance and asset performance improvement. By integrating IoT with artificial intelligence and machine

learning, EAM systems can significantly reduce operating expenses (OPEX) and capital replacement expenses (CAPEX), increase uptime, and enhance asset capability. The study underscores the importance of adopting cutting-edge technologies and standards to achieve cost savings and operational excellence in asset management (Bhanji et al., 2021).

By enabling real-time monitoring, predictive analytics, and data-driven decision-making, IoT technologies facilitate significant cost reductions, efficiency improvements, and enhanced asset performance. The success stories and case studies presented underscore the potential of IoT to revolutionize asset management practices, offering a roadmap for organizations seeking to optimize their operations and achieve financial savings.

3.4. Enhanced Accuracy in Asset Tracking and Inventory Management through IoT

Selvakumar et al. (2023) discuss the transformative potential of IoT sensors in asset management, particularly within factories, warehouses, and distribution centers. These sensors provide real-time information on the location, condition, and usage of assets, enabling organizations to optimize asset utilization and reduce costs. The study highlights how IoT sensors can monitor machinery to ensure optimal operation, identify issues before they escalate, and streamline supply chains, ultimately leading to reduced downtime, extended equipment lifespans, and improved customer satisfaction (Selvakumar et al., 2023).

Vadi et al. (2021) aim to improve inventory management efficiency through the development of a low-cost Asset Tracking and Inventory Management System (ATIM). This system enhances supply chain management by providing real-time updates on stock levels and movements, thereby improving the accuracy of inventory tracking and reducing the likelihood of stockouts or overstocking. The study discusses the benefits and challenges of implementing IoT in supply chain management, emphasizing the potential for smart, safe, and efficient store operations.

3.4.1. Advancements in Real-Time Tracking Technologies through IoT

Alazawi and Al-Khayyat (2022) discuss the design and implementation of a vehicle tracking system utilizing IoT technologies. This system leverages GPS and GSM/GPRS modules integrated with a Raspberry Pi microcontroller to monitor the speed and location of vehicles in real-time. The system's ability to automatically issue fines for speed limit breaches demonstrates the potential of IoT to enhance road safety and law enforcement. This approach not only reduces the need for expensive infrastructure but also proves to be an efficient and cost-effective solution for traffic management (Alazawi & Al-Khayyat, 2022).

Kumari, Kumar, and Khan (2020) present an IoT-based intelligent system for real-time bus tracking and monitoring, aimed at improving the safety and comfort of school children. This system allows parents, schools, and regulatory bodies to track the conditions inside buses, providing complete visibility and generating reports on various activities. The application of IoT in this context demonstrates its capability to enhance the quality of education by ensuring the safety and comfort of students during their commute.

Hong et al. (2021) propose a multitarget real-time tracking algorithm for unmanned aerial vehicles (UAVs) IoT, utilizing deep learning methods for target detection and tracking. This study highlights the integration of IoT with machine learning algorithms to achieve high-precision, real-time tracking of UAVs in urban environments. By employing the tracking-by-detection mode and the modified YOLOv3 algorithm, the system achieves a tracking accuracy of 94.4% and a speed of 54 FPS, showcasing the effectiveness of IoT in enhancing the safety and efficiency of drone operations (Hong et al., 2021).

3.5. Identified Barriers to IoT Adoption in Asset Management

The integration of the Internet of Things (IoT) into asset management systems promises to revolutionize how assets are monitored, maintained, and optimized. However, the adoption of IoT technologies in this domain faces several barriers. This section explores the identified barriers to IoT adoption in asset management, drawing insights from recent studies.

Brous et al. (2017) highlight the complexity of adopting a data-driven approach to asset management as a significant barrier to IoT integration. The study emphasizes the need for an effective data governance strategy to ensure data quality, manage expectations, build trust, and integrate IoT data into decision-making processes. Despite the potential benefits of IoT for asset management, the current level of adoption remains low, underscoring the challenges organizations face in transitioning to IoT-enabled systems.

Cheng et al. (2024) investigate the barriers to IoT adoption in the Chinese construction industry, identifying inadequate infrastructure, lack of governance, and insufficient top management support as fundamental obstacles. The study employs a mixed-method approach to explore the prioritization and hierarchical structure of these barriers, revealing the interdependence between identified constructs and their intensities. This research underscores the importance of addressing these fundamental barriers to facilitate the effective implementation of IoT in construction asset management (Cheng et al., 2024).

Sharma et al. (2020) focus on the barriers to IoT adoption in smart cities' waste management systems in India. The study identifies operational costs, payback issues, lack of standardization, regulations, and technical knowledge among policymakers as critical barriers. Internet connectivity, privacy, security issues, and insufficient IT infrastructure also pose significant challenges to IoT implementation in waste management. The research provides a structural framework of IoT adoption barriers, offering insights into the complexities of integrating IoT into smart cities' waste management practices.

Martínez et al. (2023) prioritize the barriers to IoT adoption within the clean energy context using a Fermatean fuzzy-based decision framework. The study identifies labor/workforce skill insufficiency, ineffective performance frameworks, technology divides, insufficient legislation, and lack of training time as the top barriers hindering IoT adoption. These findings highlight the multifaceted challenges organizations face in adopting IoT technologies for clean energy asset management.

4. Discussion of the Results

4.1. Analyzing the Impact of IoT on Asset Management Efficiency

Karthikamani et al. (2023) introduce an RFID-enabled IoT asset management system that integrates machine learning algorithms to enhance the accuracy and efficiency of asset tracking. The system's utilization of RFID tags for asset tracking, coupled with Gradient Boosting and Random Forest algorithms for data processing, demonstrates a marked improvement in tracking accuracy over traditional methods. This integration not only improves operational efficiency but also reduces the likelihood of asset misplacement or theft, showcasing the potential of IoT technologies to revolutionize asset management practices (Karthikamani et al., 2023).

Aravindaguru et al. (2023) explore the application of IoT and cloud computing technologies in industrial wastewater management. Their study presents a cloud-based IoT system for real-time monitoring, which offers significant advantages over traditional systems, including increased efficiency, remote access, and real-time data processing. The ability to analyze data in real-time and make informed decisions promptly highlights the efficiency gains IoT systems can offer to the management of industrial assets (Aravindaguru et al., 2023).

Tanne et al. (2023) develop a conceptual framework for integrating Technology 4.0, including IoT sensors and devices, into urban road asset management. This framework aims to improve service delivery, travel efficiency, and security by utilizing advanced technologies for data collection and analysis. The proposed integration of IoT technologies into urban infrastructure management illustrates the potential for IoT to enhance the efficiency and effectiveness of public asset management (Tanne et al., 2023).

Khaleefah et al. (2023) investigate data reduction techniques for optimizing IoT data transmission in smart agriculture, comparing these techniques to traditional data management methods. Their study highlights the trade-offs between information loss, computational cost, and energy consumption in IoT systems. The findings underscore the importance of selecting appropriate data reduction techniques to balance efficiency and data integrity, further emphasizing the nuanced advantages of IoT in asset management (Khaleefah et al., 2023).

4.1.1. Comparative Analysis with Traditional Asset Management Systems

The integration of Internet of Things (IoT) technologies into asset management systems heralds a paradigm shift from traditional methodologies, characterized by manual tracking and data processing, to a more automated, efficient, and accurate approach. Karthikamani et al. (2023) illustrate this transition through the development of an RFID-enabled IoT asset management system, which significantly enhances the accuracy and efficiency of asset tracking. This system, leveraging Machine Learning algorithms for data analysis, underscores the superiority of IoT-based systems over traditional methods in terms of precision, recall, and error rate reduction.

Similarly, the work of Aravindaguru et al. (2023) in the realm of wastewater management demonstrates the advantages of IoT and cloud computing technologies in real-time monitoring and management. The transition to a cloud-based IoT system facilitates immediate data processing and access, offering a stark contrast to the time-consuming and error-prone manual data collection and analysis characteristic of traditional systems. This shift not only enhances operational efficiency but also promotes proactive management practices.

In the context of urban road asset management, Tanne et al. (2023) propose a conceptual framework that integrates Technology 4.0, including IoT sensors and devices, for improved management of road assets. This approach, aimed at addressing maintenance issues more effectively than traditional methods, highlights the potential of IoT technologies to revolutionize public asset management through advanced data analysis and decision-making capabilities.

Furthermore, the study by Khaleefah et al. (2023) on optimizing IoT data transmission in smart agriculture presents a comparative analysis of data reduction techniques, revealing the trade-offs between information loss, computational cost, and energy consumption. This analysis not only showcases the complexity of managing IoT-generated data but also emphasizes the efficiency gains achievable through the careful selection of data processing techniques, as opposed to the more straightforward but less efficient data handling methods of traditional systems.

The comparative analysis underscores the transformative potential of IoT technologies in asset management, offering a roadmap for organizations seeking to navigate the complexities of digital transformation. As these technologies continue to evolve, their integration into asset management systems promises to redefine the landscape of operational efficiency and strategic asset utilization.

4.2. Security Implications of IoT in Sensitive Asset Tracking

The integration of Internet of Things (IoT) technologies into sensitive asset tracking systems has revolutionized the way organizations monitor and manage their resources. However, this technological advancement comes with significant security implications that must be carefully managed to protect against data breaches and cyber threats. Steinel et al. (2019) highlight the privacy trade-offs inherent in location tracking of mobile objects, emphasizing the need for a balance between data integrity and privacy. This balance is crucial in sensitive asset tracking, where the unauthorized disclosure of location data could have severe consequences.

The proliferation of IoT devices has expanded the attack surface for cybercriminals, introducing new vulnerabilities in asset tracking systems. Almagrabi (2022) discusses the challenges and vulnerabilities of smart cities in the context of IoT devices, pointing out that security and privacy are paramount concerns that must be addressed to fully realize the potential of IoT technologies. The interconnected nature of IoT devices means that a breach in one device could potentially compromise an entire network, underscoring the importance of robust cybersecurity mechanisms.

The security implications of IoT in sensitive asset tracking demand a comprehensive and dynamic approach to cybersecurity. Organizations must prioritize the protection of sensitive data and invest in advanced security technologies and practices to mitigate the risks associated with IoT deployments. By doing so, they can leverage the full potential of IoT technologies while ensuring the security and privacy of their assets.

4.2.1. Addressing Data Privacy and Cybersecurity Concerns

The rapid expansion of the Internet of Things (IoT) into various sectors has significantly increased the efficiency and effectiveness of asset management systems. However, this integration has also introduced complex challenges in data privacy and cybersecurity, necessitating robust strategies to safeguard sensitive information.

Irwansyah et al. (2023) delve into the unique cybersecurity risks posed by the proliferation of IoT devices, highlighting the importance of encryption, authentication, and intrusion detection systems in protecting interconnected systems and data. The study underscores the evolving threat landscape and the need for a holistic cybersecurity approach that integrates technological advancements with robust policies and user awareness to mitigate IoT-related risks effectively.

Adebiyi and Olayemi (2022) explore the impact of perceived data privacy risks on consumer behavior, revealing a significant concern among users regarding the security of their data in IoT applications. The study suggests that heightened awareness of data privacy and cybersecurity risks can influence consumer trust and engagement with IoT devices, underscoring the importance of transparent and secure data handling practices.

Alajlan et al. (2023) review the cybersecurity challenges of blockchain-based IoT systems, identifying key areas such as IoT device security, blockchain security, and the integration of IoT devices with blockchain. The authors propose future

research directions to address these challenges, highlighting the potential of blockchain technology to enhance the security and privacy of IoT systems through decentralization, transparency, and data integrity.

The integration of IoT in asset management systems offers unparalleled opportunities for real-time monitoring and management of assets. However, the interconnectedness of IoT devices increases the attack surface, raising significant concerns about cybersecurity vulnerabilities and potential data breaches. Ensuring robust security measures, including secure device authentication, encryption, and regular firmware updates, is crucial to safeguard against unauthorized access and potential data compromises.

Despite the challenges, the benefits of IoT in enhancing the efficiency and effectiveness of asset tracking systems cannot be understated. The real-time monitoring and management capabilities provided by IoT technologies offer significant advantages over traditional asset tracking methods. However, achieving these benefits requires a proactive approach to security and privacy, with continuous evaluation and adaptation of security measures to address emerging threats.

4.3. Strategic Recommendations for Overcoming IoT Integration Challenges

The integration of Internet of Things (IoT) technologies into asset management systems presents a unique set of challenges, ranging from technical hurdles to strategic alignment issues. Steffen et al. (2013) highlight the importance of coordinating strategic and operational asset management to improve the efficiency of asset planning and operational execution. This coordination is crucial for overcoming integration challenges, suggesting that a practical and simple solution can significantly enhance the integration process by automating data provision and supporting real-time commissioning through strategic and operative project comparisons.

Ylä-Kujala et al. (2016) emphasize the benefits of inter-organisational asset management, linking operational and strategic views to address coordination and management challenges. Their research demonstrates that collaborative economic value creation at both operational and strategic levels can address some of the integration challenges faced by organisations. This approach not only facilitates the management of interdependencies but also highlights the importance of understanding the cause-and-effect relationship between operational decisions and strategic outcomes.

Addressing technical challenges requires a focus on improving data transmission channels, developing robust hardware for extreme conditions, and conducting targeted user education campaigns to mitigate resistance from users accustomed to conventional systems. Implementing IoT-specific protocols and capabilities will facilitate efficient data management, ensuring the secure and effective operation of IoT devices.

The strategic integration of IoT technologies into asset management systems necessitates a multifaceted approach that addresses both technical and organisational challenges. By focusing on strategic alignment, inter-organisational collaboration, and robust data management strategies, organisations can effectively overcome the hurdles associated with IoT integration and harness the full potential of these technologies to enhance asset management efficiency.

5. Conclusion

In the labyrinthine evolution of asset management within the digital epoch, this study embarked on an exploratory voyage, aiming to dissect the intricate interplay between Internet of Things (IoT) technologies and asset management paradigms. Anchored by a meticulously crafted objective, the research endeavored to illuminate the transformative potential of IoT, delineating its integration challenges, and unfurling strategic recommendations to navigate these complexities. Through the prism of a qualitative research approach and a systematic literature review, the study meticulously curated a compendium of insights, thereby scaffolding the edifice of its investigative pursuit on a robust methodological foundation.

The findings of this scholarly inquiry underscored a significant enhancement in asset utilization rates, attributed to the incisive application of IoT technologies. This revelation was further embellished with empirical vignettes, manifesting in case studies that chronicled the success stories of IoT integration within the asset management sphere. Moreover, the research illuminated the economic prudence of IoT adoption, evidenced by marked reductions in asset maintenance and operational expenditures. The precision and accuracy in asset tracking and inventory management, augmented by advancements in real-time tracking technologies, emerged as a salient theme, heralding a new era of efficiency and effectiveness in asset management.

However, the odyssey through the IoT landscape unveiled barriers—technical, organizational, and cultural—that stymie the seamless adoption of these technologies. Addressing these impediments, the study proffered strategic

recommendations, advocating for a harmonious blend of technical ingenuity and strategic foresight. The emphasis on strategic alignment, inter-organisational collaboration, and robust data management strategies crystallized as pivotal levers to surmount integration challenges.

In conclusion, this scholarly endeavor not only achieved its aims and objectives but also contributed a panoramic vista on the symbiosis between IoT technologies and asset management. It charted the contours of a future where asset management is not merely a functional necessity but a strategic asset, powered by the innovative prowess of IoT technologies. The recommendations posited herein serve as a beacon for organizations navigating the IoT integration odyssey, promising a horizon brimming with efficiency, efficacy, and economic viability.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have no conflict of interest to disclose.

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