Smart Technology Usage on Warehouse Management Performance

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ABSTRACT

As technology is developing day by day, and facing the revolution of the 21st century which is Industrial Revolution 4.0 where civilization and human activities are more modern with the help of technology beyond our expectations. This research paper emphasizes the relationship between the smart technology usage in warehouse and the warehouse management performance. With the rapid growth of technologies in the world today, various types of technologies have been used in the warehouse to increase the warehouse performance. Warehouses are progressively incorporating smart technology to enhance overall performance, accuracy, and efficiency since the introduction of Industry 4.0. The analysis of the impact of smart technology usage on warehouse management, including data analysis, artificial intelligence, automated systems, and Internet of Things (IoT) integration, is the main goal of this study. With an emphasis on how developments in automation, data analytics, and Internet of Things (IoT) devices improve operational efficiency, accuracy, and decision-making processes in contemporary warehousing environments, this study explores the impact of smart technology on warehouse management performance. The results show that by lowering human error, improving inventory control, and raising overall productivity, the deployment of smart technology significantly enhances warehouse performance. The report also identifies difficulties such the high upfront expenditures and the requirement for qualified staff to operate and maintain these cutting-edge devices. The findings highlight how important smart technology will be in influencing warehouse management going forward and offer practical advice to businesses trying to improve their operational efficiency and competitive advantage.

Keywords: Smart technology, Automated System, Artificial Intelligence, Big Data analytic, Internet of Things, Radio-Frequency Identification, Warehouse Management, Performance

INTRODUCTION

The integration of smart technology into warehouse management has become a key tactic in the logistics business for improving competitiveness and operational efficiency. To optimize many elements of warehouse operations, warehouses are progressively implementing smart technologies with the introduction of Industry 4.0, including data analytics, automated systems, Internet of Things (IoT) devices, and artificial intelligence (AI). Real-time monitoring, predictive analytics, and process automation are made possible by this integration, which has the potential to completely transform conventional warehouse management procedures. According to a report by Markets and Markets, at a compound annual growth rate (CAGR) of 14.6% over the course of the projection period, the smart warehousing market is expected to increase from USD 20.4 billion in 2023 to USD 40.5 billion by 2028. Smart warehousing is anticipated to develop rapidly during the forecast period due to numerous businesses. The sophistication of warehouses is changing the expectations of customers. Modern client needs cannot be met by conventional warehouses. Using intelligent warehousing technology is necessary to solve the problems that modern supply chains are facing.

The use of smart technology in warehouse operations has become an essential strategy in today's supply chain management environment for boosting productivity, competitiveness, and efficiency. It is critical to comprehend the connection between smart technology features and warehouse management performance as warehouses move towards becoming more automated, networked, and data driven. A wide range of usage are included in smart technology, such as robotics, data analytics, Internet of Things (IoT) sensors, artificial intelligence (AI), and more. Each of these technologies makes a distinct contribution to the optimization of warehouse activities.

Thorough research is necessary to understand how these traits interact and how they affect warehouse management's key performance indicators (KPIs). Reputable supply chain management expert Dr. Larry Lapide in 2018 highlights how revolutionary smart technologies can be, saying that “smart technology integration in warehouses has the capacity to revolutionize traditional operations, enabling real-time visibility, predictive analytics, and seamless automation”. His claim emphasizes how important it is to employ the features of smart technology to promote operational effectiveness in warehouse settings.

Additional evidence of the importance of data analytics in enhancing warehouse performance comes from Dr. Michael Feindt, a company's founder, and chief scientific advisor, who says that "data-driven decision-making facilitated by advanced analytics empowers warehouses to adapt dynamically to changing demand patterns, minimize inventory holding costs, and maximize resource utilization" (Feindt, 2019). This demonstrates how important it is to employ the data analytics features that are built into smart technology to guide strategic decision making in warehouse management.

The revolutionary potential of smart technology in warehouse management is highlighted in the foundational works of Lapide and Feindt, which also provide a basis for future research into the subtle effects of these usage on performance results. By using a thorough analytical framework to clarify the connections between smart technology features and warehouse management performance, this study aims to go deeper into this relationship.

Smart technology integration is becoming more and more common in the context of contemporary warehouse management, offering increased operational efficiency, accuracy, and productivity. Though the potential advantages of smart technology in warehouse environments are becoming more widely acknowledged, it is still unclear how exactly these features relate to the effectiveness of warehouse management. There is a lack of empirical research that systematically examines how the various attributes of smart technologies like artificial intelligence applications, automated machinery, data analytics platforms, and Internet of Things systems affect key performance indicators in warehouse operations, even though these technologies are widely used in warehouses. To make wise decisions about the adoption of technology, the distribution of resources, and the optimization of processes, warehouse managers and other stakeholders must have a thorough understanding of this relationship.

In the modern business environment, warehouses play a big part in meeting client expectations. It is a major source of competitiveness, determined by who can supply goods more quickly while maintaining greater flexibility and cost effectiveness. Accordingly, managers must be extremely knowledgeable about all aspects of storage and how they impact the entire supply chain (Richards, 2017). According to Trappey et al. (2017), a warehouse's ability to accurately and quickly meet requests, reduce non-value-added operations, and have efficient management are all indicators of its progress. The information integration, which includes essential features for order administration, product tracking, and inventory status updates, is another issue. Consequently, there is an urgent need for empirical research that explores the complex relationship between warehouse management performance and smart technology attributes. This research aims to provide actionable insights and guidelines for warehouse managers to optimize their operations in an increasingly digitized and competitive landscape by identifying the specific smart technology features that contribute most significantly to performance outcomes, such as labor productivity, order fulfilment speed, accuracy, and space utilization efficiency.

By investigating how specific smart technology features, such as automation, real-time data analytics, and IoT integration, correlate with operational efficiency, inventory management, and overall productivity, the research provides valuable insights for warehouse operators and logistics managers. Understanding these relationships is crucial for identifying which technological advancements are most beneficial, enabling businesses to make informed decisions about technology investments that can lead to enhanced performance, reduced operational costs, and improved customer satisfaction. Additionally, the study's objective to determine the most significant effects of smart technology usage on warehouse management performance has practical implications for the industry. By pinpointing which technologies yield the highest performance improvements, the findings can guide strategic planning and resource allocation in the logistics sector. This knowledge is particularly valuable in an era where technological innovation is rapidly transforming supply chain dynamics. Companies can leverage these insights to prioritize the adoption of high-impact technologies, thereby gaining a competitive edge in the

market. Furthermore, policymakers and industry regulators can use the study's outcomes to formulate standards and guidelines that promote the effective integration of smart technologies, fostering a more efficient and resilient logistics infrastructure.

LITERATURE REVIEW

The examination of the past research literature provides an understanding on the influence of smart technology characteristic on warehouse management performance, by exploring the evolution and different types of smart technologies, including automation, Internet of Things (IoT), and real-time data analytics, and their applications in warehouse settings. The review then delves into various studies and theoretical frameworks that examine the impact of these technologies on key performance indicators such as operational efficiency, inventory accuracy, and cost reduction.

Smart Technology

Smart technologies refer to mechanical systems that are outfitted with sensors, actuators, and pre-programmed controllers. These systems enable a structure to adjust to erratic external loading circumstances. Understanding the mechanical system itself, embedded sensors and controlled devices which is often built on smart materials and driving electronics with integrated software which provides intelligence to the system are all necessary for comprehending the idea of smart technologies. According to Evie Garcia (2019), data-driven algorithms are used by networked devices and systems to automate operations, optimise workflows, and enhance decision-making. The author also highlights the value of connection and intelligence in smart technology solutions. It makes the case that smart technology makes it easier for devices to communicate with one another and with each other, allowing them to share information, keep an eye on their surroundings, and react wisely to commands or changes. Eventually, it also highlights on how smart technology may revolutionize several industries, such as manufacturing, transportation, and healthcare. Smith (2020) offers a balanced view on smart technology, where he portrays that smart technology encompasses a comprehensive approach to innovation that incorporates advanced sensors, artificial intelligence, and data analytics, going beyond simple automation and connectivity. Based on this definition, real-time data collection, analysis, and action to improve user experience, optimize performance, and spur profit creation are the hallmarks of smart technology. It also highlights the dynamic nature of smart technology and how it is enabling new business models and altering established sectors (Smith, 2020). These two viewpoints highlight the transformational potential and broad applicability of smart technology across several industries, providing insightful analysis of its complex nature.

Internet of Things (IoT)

The influence of IoT, Industry 4.0 and various other emerging technologies is evident in shaping the dynamics of information exchange within warehouses. A study by Ben-Daya et al. (2017) elucidates the significance of IoT and its implications on the management of supply chains. Manavalan and Jayakrishna (2019) critically examine the contribution of IoT in attaining sustainable objectives within the realm of supply chain management. The analysis delves into the significance of digitalization and the impact that IoT exerts on the holistic management of supply chains. The study culminates in determining the prerequisites necessary for businesses to be adequately prepared for the transformative processes associated with Industry 4.0., whereas Winkelhaus and Grosse (2020) present a structured examination of existing literature pertaining to Logistics 4.0.

Industrial warehouses, in comparison to traditional warehouses, can implement a unique warehouse management system (WMS). An example of such a system is the Duta system, where the description of incoming products is logged. Furthermore, outgoing products are incorporated into the system upon arrival to enhance inventory management. Each article within the system is assigned a code to facilitate easier article summarization (Affia & Aamer, 2021). The crucial step in the inventory process involves entering items specifics. Typically, warehouse personnel manually handle the income process and record-keeping, thereby increasing the likelihood of data entry errors due to human error (Arumsari & Aamer, 2022). Apart from managing goods, industrial warehouses

also accommodate a significant workforce. These employees are responsible for overseeing the flow of items within the warehouse. Warehouse managers often require transparency and personnel information to facilitate their responsibilities. Regrettably, the task of obtaining employee attendance data can sometimes prove to be challenging due to the utilization of a manual attendance system. The conventional approaches often fall short in effectiveness, with data loss occurrences being frequent, potentially stemming from human errors (Zhen & Li, 2022). The incorporation of IoT into Warehouse Management Systems (WMS) is poised to bring substantial benefits to warehouse employees as they carry out their tasks, ultimately enhancing warehouse productivity and refining existing work protocols.

H1: There is a significant relationship between Internet of Things (IoT) usage and warehouse management performance.

Automated system (robotic)

Warehousing is frequently perceived as a labor intensive operation. The management of conventional manual warehouses has emerged as a pressing issue for enhancing performance, characterized by a high level of complexity (Yu & de Koster, 2009). To address this concern, many warehouses have resorted to the adoption of automation technology. Automation which involves the utilization of technology to carry out tasks with minimal human intervention, has brought about various transformations in warehouse operations. These changes encompass improved efficiency, swift responsiveness to customer orders, as well as substantial reductions in both labor expenses and errors. Notably, automated parts-to-picker order picking systems have gained popularity within warehouse settings (Tappia et al., 2019). The proliferation of automation facilities has been substantial, leading to the increased complexity of devising optimal strategies for designing and managing automated warehouse systems due to the rapid advancement and integration of modern computer technology (Amato et al., 2005). When integrating automation technology into warehouse operations and design, it is crucial to explore the interconnectedness of strategic and tactical decisions alongside certain system usage. Essentially, it involves a blend of automatic machinery and corresponding control protocols (Khojasteh & Son, 2016). Despite the extensive adoption of AS/RS over the years, research on its operational decision-making remains highly valuable, offering fundamental insights for various technological applications in smart warehousing.

H2: There is a significant relationship between automated system usage and warehouse management performance.

Big Data analytics

The term "big data analytics" describes the procedures, equipment, and software used to gather, handle, and interpret diverse, high-volume, high-velocity data sets to get insights. Numerous sources, including the web, mobile, email, social media, and networked smart devices, could provide these data sets. They frequently contain data that is produced quickly and in a variety of formats, including unstructured (pictures, audio files) and semistructured (XML files, webpages) data (database tables, Excel sheets). Big data analysis systems, tools, and applications are different from traditional kinds of data analysis software in that they are built to handle large amounts of data and complexity.

Big Data technologies are crucial to the implementation of Industry 4.0 and Logistics 4.0 as well as the resolution of the primary issues they raise. This is because they can analyze vast amounts of diverse data flowing at a high speed (Strandhagen et al, 2018). Panetto et al. (2025) state that big data technologies play a critical role in the implementation of Industry 4.0 and Logistics 4.0 as well as in addressing the primary challenges that come with them due to their capacity to analyse vast amounts of diverse data flowing at a high velocity. In addition to the impact of ideas like Industry 4.0 and Logistics 4.0, investments in Big Data technologies are growing, maturing and becoming more robust, so that they may be integrated into businesses and used internally.

H3: There is a significant relationship between Big Data analytics usage and warehouse management performance.

Artificial intelligence

Artificial intelligence (AI) is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. AI is such a huge umbrella beneath which exists everything; From narrow to general AI also powered by the excellent applications of AI you have neural networks and even machine learning. AI could improve productivity, reduce error rates, and introduce creative solutions, making it a potentially disruptive force for good industries including healthcare, banking, transportation, and entertainment.

One must acknowledge the realities of computer technology breakthroughs to embrace Industrial Revolution 4.0 (4IR). Many systems related to physical technology and human life have been impacted by modern computer technology. This is referred to as practicing artificial intelligence (AI). Computing systems intended to emulate human behaviour, and duties are premised on artificial intelligence (Schalkoff, 1990; Russel & Norvig, 2003). Artificial Intelligence (AI) is a wide and huge field which offers total slavery of robotics, digital & artificial technology. The ability of information technology to store knowledge about recording, modelling, and reproducing human intelligence, behaviour explanation or reproduction (human activity simulation), training or programming systems for performing tasks that could be performed by humans has been brought to a new level with the development of artificial intelligence in recent years (Russel & Norvig, 2016). AI helps in terms of warehouse management in terms of reducing cost, optimizing process, and improving efficiency. AI also can help in terms of forecast demand, controlling demand, expedite packing and order picking. Automation and robotics powered by AI will reduce the labor cost and decrease the possibility of human error. AI driven system also improve the layout design and space utilization, leading to faster operation. It also improves inventory control and ultimately boosting better decision making.

H4: There is a significant relationship between artificial intelligence usage and warehouse management performance.

Radio-Frequency Identification (RFID)

RFID technology operates on radio waves to facilitate automatic object identification and data collection. Within the realm of interconnection technologies, RFID stands out as a preferred option for tasks such as positioning, identification, information exchange, and warehouse management within smart warehouses. Its advantages encompass non-invasive sensing capabilities, high adaptability, configurability, efficiency, and costeffectiveness. In the study conducted by Giusti et al. (2019), a comprehensive model for comparing the performance of various RFID implementations is presented. The impact of informatization on warehouse performance is thoroughly examined, utilizing a probabilistic risk assessment model to pinpoint and quantify delays in transfer time is a crucial aspect to consider.

According to Lam et al., (2015), the real-time information exchange and the gathering of RFID data have the potential to be an important decision support tool for streamlining order fulfilment procedures. Furthermore, by improving energy efficiency, the integration of RFID technology may bring a new level of complexity to warehouse operations. The utilization of Radio Frequency Identification (RFID) technology within intelligent warehouses predominantly emphasizes inventory monitoring, localization, and overall warehouse management. Central to the RFID system is the exchange of information, which plays a pivotal role in enhancing communication efficiency within warehouses. The accuracy of information holds paramount importance in optimizing the efficiency and effectiveness of warehouse information exchange (Zhong et al., 2015). Object localization, a key function facilitated by RFID technology, is fundamental in the realm of RFID warehouse management. An intricate challenge encountered in RFID-based applications pertains to obtaining precise location information of tags or readers. Consequently, RFID-based localization, particularly in threedimensional space, has emerged as a prominent area of research interest (Lu et al., 2018). Scholars have also delved into investigating the tracking of inventory (Shahzad & Liu, 2015; Zhou et al., 2017; Mo & Li, 2019; Gareis et al,. 2021). The search for missing tags represents yet another application of RFID technology in object localization and inventory tracking (Chen et al., 2017).

H5: There is a significant relationship between Radio-Frequency Identification (RFID) usage and warehouse management performance.

Warehouse Management Performance

The design of contemporary logistics warehouses and distribution hubs involves a number of optimization analyses. Warehouses these days need a lot of care. Cakmak et. al. (2012) define a warehouse as a location where raw materials, semi-finished items, and finished goods are acquired, transferred, or kept. They are also harvested, sorted, and collected. Next, they are pass-docked and shipped in. The process of efficiently and effectively managing every activity that takes place in a warehouse, such as receiving, storing, picking, packaging, and delivering items or products, is known as warehouse management. Ensuring that the correct products are available in the right amounts, at the right times, and at the right places to meet consumer demand while reducing costs and optimizing operating efficiency is the main objective of warehouse management.

According to Simchi-Levi (2020), warehouse management includes both operational and strategic tasks necessary for the effective handling, storage, and transportation of commodities inside a warehouse. To save expenses, shorten lead times, and increase customer satisfaction, he stresses the significance of optimizing warehouse operations. It emphasizes on how technology, including automation and warehouse management systems (WMS), can increase the accuracy and efficiency of warehouse operations. On the other hand, Waters (2016) defines warehouse management as the methodical planning, arranging, and regulating of warehouse activities to guarantee the precise and timely flow of goods from receipt through storage and dispatch. He highlights that to maximize space utilization and reduce handling costs, warehouse layout design, inventory management, and resource allocation must all be done effectively. Waters emphasizes that to improve overall efficiency and competitiveness, warehouse management techniques must be and in line with more general supply chain goals.

Logistical efficiency is rising because of information technology advancements (Straka et al., 2018). This is the justification for the choice to implement a WMS in the organization that is having significant problems with storage. Smart technology integrates cutting-edge systems like automation, IoT, and real-time data analytics to dramatically improve warehouse management performance. These technologies increase overall efficiency, increase inventory accuracy, and streamline processes. IoT devices allow real-time tracking and monitoring, automation lowers human labour and errors, and data analytics provide useful information for improved decision-making. As a result, warehouses may increase productivity, lower operating costs, and provide better service, all of which contribute to a logistics environment that is more effective and competitive.

Method

This research uses quantitative research design specifically exploratory research. Questionnaires are distributed to respondents which is the employees of a significant aviation hub in West Malaysia. The research closely examined the impact of smart technology usage on the warehouse management performance.

RESULTS AND DISCUSSION

Descriptive analysis

Data were collected from 168 employees whom directly involved with smart technologies and warehouse operation.

Age, education level, position, level of smart technology familiarity in the warehouse operations, and frequency of smart technology usage are all personal information considered in this study.

The age range of the respondents is between 18 and 40 years old. 17.3% of the respondents are in the range of age 18-24 years old, while the respondents in their 40 years and above only the 19.4% of the respondents. The largest group is aged between 35-44 years at 33.2%, followed by those aged between 25-34 years at 30.1%.

These groups constitute the majority and are likely to represent individuals in mid-career or management levels that play a key role in adopting and implementing smart technologies as well directly evaluating the performance.

As for position in the company, majority of the respondents are from the warehouse inventory clerks, which is at 39.3%, followed by package handlers with percentage of 23.5%. The remaining portion of respondents is distributed across general labor roles at 17.3%, data analyst roles at 11.7%, and warehouse operation manager roles at 8.2%.

Most of respondents, at 50% of respondents are relatively familiar (with basic understanding) with the smart technology in warehouse operation, while 28.1% are not familiar with the smart technology while the remaining 21.9% of respondents were very familiar.

As for the frequency of smart technology usage in warehouses, occasionally, 36.2% employees used IoT and 32.7% employees used artificial intelligence technology respectively. Meanwhile, in terms of weekly frequency, 32.1% of respondents uses automated systems, 37.8% employees used Big Data analytic system in the warehouse operation and 32.7% of employees used the RFID respectively.

Correlation analysis

The Pearson Correlation test examined the relationship between independent (the usages of *Internet of Things (IoT), automated system, Big Data analytics, artificial intelligence and Radio-Frequency Identification Devices (RFID)*) and dependent variable (warehouse management performance). The outcome of the correlations is summarized in Table 1. As shown in Table 1, all variables are significantly linked to the usage of smart technology effects on the warehouse performance. As a result, it indicated that, Artificial Intelligence (AI) has the highest correlation value with 0.925 which is significant at <0.01 level (2 tailed). Big Data Analytic, on the other hand, has the lowest correlation value of 0.809, which is significant at the <0.01 level.

Table 1: Pearson Correlations

		Things (IoT)	Automated System	Big Data Analytic	Artificial Intelligence	RadioFrequency Identification Device (RFID)	Warehouse Management Performance
Internet of Things (IoT)	Pearson Correlation	1	.867**	.843**	.864**	.933**	.896**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001	<.001
Automated System	Pearson Correlation	.867**	1	.889**	.872**	.861**	.862**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001	<.001
Big Data Analytic	Pearson Correlation	.843**	.889**	1	.729**	.953**	.809**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001
Artificial Intelligence (AI)	Pearson Correlation	.864**	.872**	.729**	1	.728**	.925**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001	<.001
Radio Frequency Identification Device (RFID)	Pearson Correlation	.933**	.861**	.953**	.728**	1	.824**
	Sig. (2-tailed)	<.001	<.001	<.001	<.001		<.001
Warehouse Management Performance	Pearson Correlation	.896**	.862**	.809**	.925**	.824**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	<.001	

Multiple Regression analysis

Multiple regression analysis was utilized in this study to investigate at the impacts of independent variables (the usages of Internet of Things (IoT), automated system, Big Data analytics, artificial intelligence and RadioFrequency Identification Devices (RFID)) and dependent variable (warehouse management performance). The results of multiple regression analysis for warehouse management performance are summarised in Table 2.

Table 2: Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.952[a]	.907	.904	1.02023

The R-square value was .907, indicating that the four independent variables can explain 90.7 percent of the variance in the performance in the warehouse. Other variables not examined in the study influenced the remaining 9.3 percent. The Adjusted R Square, therefore, considers model complexity and results in a very high explanatory power of 0.904.

Empirical Results

Table 3 has shown that all proposed determinants are significantly associated with the warehouse management with coefficient estimation of Artificial Intelligence (AI) with Beta value at 1.421 and p value of <0.001. While less noticeable and not statistically significant of p value of 0.182, Radio Frequency Identification Device (RFID) also has a positive impact on the warehouse performance with a Beta value of 0.551, where Big Data Analytics (BDA)'s Beta value at 0.126, indicating that both coefficients still promote performance enhancements even with small or less relation to the warehouse performance.

The sign of the regression standardized estimate (Beta) represents the positive or negative impact of the predictors on the dependent variable. Therefore, it can be stated that only three determinants (AI, RFID and BDA) have positive effect on the warehouse performance with the application of smart technologies in the operations.

Table 3: Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Constant	1.572	.640		2.455	.015
	Internet of Things	-.026	.314	-.016	-.084	.933
	Automated System	-.272	.128	-.160	-2.127	.035
	Big Data Analytic	.126	.276	.073	.455	.650
	Artificial Intelligence	1.421	.178	.776	7.978	<.001
	Radio-Frequency Identification Device	.551	.411	.342	1.340	.182

With reference to Table 3, the regression equation is as follows:

Smart Technology usage on Warehouse Performance	= 1.572 - 0.026 (IoT) – 0.272 (AS) + 0.126 (BDA) + 1.421 0.551 (RFID)

DISCUSSION AND RESEARCH IMPLICATIONS

This study had interpreted and contextualized the model to identify and suggest a few factors, that may influence the warehouse management performance of an organization. The final noteworthy theoretical contribution

explains and defines the relationship between the types of smart technologies and the performance in the warehouse management. The research has congruent similarity with the study done in Germany by Wehner et. al., (2025), where the research also aids academic scholars and practitioners by conceptualizing and validating the usage of smart technology on the performance of the operation.

The overall findings provide important information that may help businesses in decision making process related to warehouse management.

In this study, Artificial Intelligence (AI) has the most significant influence on the performance of warehouse management, which value of Beta at 1.421, as well as evidenced by its high statistical significance ($p < 0.001$), which further supports its considerable influence. Artificial Intelligence enables proactive management of inventory, demand forecasting, and streamlined workflows, proving to be a very important driver for enhanced warehouse performance. The focus of firms should be on AI-driven solutions to optimize key performance metrics, reduce costs, and increase productivity. As AI technology continues to evolve, its role in revolutionizing warehouse operations is expected to expand, making it a vital component for achieving sustainable competitive advantages in modern supply chain management.

The negative coefficient of Automated System and Internet of Things are -0.272 and -0.26 respectively, on the other hand, suggests that increased in both smart technologies integration may be associated with worse performance. This association is statistically significant with, $p = 0.035$ and $p=0.933$. The result of the Internet of Things might likely due to the uneven or restricted use of Internet of Things technology, where systems and devices may not be completely integrated or used to their full capacity. Furthermore, underutilization may result from early adoption and inadequate training, which would limit the potential of IoT to enhance performance indicators like order fulfilment and inventory accuracy. Thus, it means that the implementation of IoT technologies alone cannot be guaranteed to improve the performance of warehouse operations. Nevertheless, it is indicating that more research is necessary to fully understand any potential implementation issues with Automated Systems and Internet of Things.

Though its lack of statistical significance with value p at 0.650, that suggests a restricted impact in the current setting, Big Data Analytics with Beta value of 0.126, has a minor positive coefficient that implies a slight positive influence on warehouse performance, perhaps due to its current implementation is not strongly affecting the operational outcomes. While Big Data Analytics holds promise for enhancing decision-making through insights from large data sets, this would likely depend on how well it has been integrated into warehouse processes and whether data is effectively used to drive strategic and operational improvements. This finding underlines the fact that it is not only important to adopt Big Data Analytics but also to apply it rightly in the field of warehouse management. Further attempts to align Big Data capabilities with specific performance goals may yield its full potential in bringing efficiency, accuracy, and overall improvement in the functioning of warehouses.

Finally, these results highlight that Artificial Intelligence as the most significant driver, with Internet of Things and Big Data Analytics contributing less, and the adverse influence of Automated Systems suggesting potential implementation issues.

CONCLUSION

This research adds to the expanding collection of study on the usage of advanced smart technology application on the operation performance specifically in the warehouse management perspective. The results indicate that Artificial Intelligence (AI) is the most influential smart technology usage on the warehouse performance, whereas automated system (AS) has the inconsequential influence on the performance. This research enhances the comprehension of usage of smart technologies in businesses despite the advancement of technologies worldwide. The study's findings have vital implications for the expanding knowledge as well as in industry that aims for sustainable warehouse management in specific.

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