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I-CReST 2025:105-076 – Evaluating the Impact of Autonomous Mobile Robots on Warehouse Efficiency in a Malaysian Retail Pharmacy Chain

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ABSTRACT

This study investigates the operational impact of Autonomous Mobile Robots (AMRs) in the warehouse of a Malaysian retail pharmacy chain navigating the complexity of omni-channel fulfilment. The research addresses a key problem: how mid-sized warehouses can scale efficiency without major infrastructure overhaul in the face of high SKU variability and fluctuating order volumes. A mixed-methods design was used, combining survey data (n=30) based on the Unified Theory of Acceptance and Use of Technology (UTAUT) and interview insights (n=7) aligned with the Supply Chain Agility and Resilience (SCAR) framework. Quantitative findings revealed a significant increase in picking accuracy from 94% to 99.95%, with a 50% reduction in peak manpower requirements. Regression analysis confirmed performance expectancy ($\beta = 0.383$, $p = .044$) and facilitating conditions ($\beta = 0.406$, $p = .032$) as strong predictors of employee intention to use AMRs. Qualitative insights supported these findings and highlighted the AMRs' ability to reduce physical strain and structure workflow, while also exposing critical dependencies on backend systems. Fulfilment continuity was vulnerable to Wi-Fi signal drops below -50 dBm and inaccurate SKU metadata, which caused system interruptions and rack failures. Nevertheless, AMR integration enabled a 30.7% increase in inventory value stored within the same footprint and improved throughput during campaigns, reaching up to 22,000 order lines daily. These results suggest that AMRs can act as scalable, labour-efficient solutions when paired with reliable digital infrastructure and well-planned operational redesign. The study concludes that while AMRs alone do not solve all fulfilment challenges, they significantly enhance agility and productivity in resource-constrained retail environments, offering a replicable model for automation in Southeast Asia's emerging logistics sector.

Keywords: Autonomous mobile robots; warehouse automation; supply chain agility; technology adoption; omni-channel logistics

1. INTRODUCTION

The retail pharmacy industry has experienced unprecedented shifts driven by the growing demand for efficiency, accuracy, and resilience in supply chain operations. These changes are particularly evident in warehouse management, where traditional manual processes often fall fail to meeting the requirements of modern omnichannel retailing. The recent COVID-19 pandemic exposed vulnerabilities in supply chains worldwide, accelerating the adoption of automation technologies [1], [2] to enhance productivity and mitigate human resource constraints. Among these technologies, Autonomous Mobile Robots (AMRs) have gained significant attention for their potential to transform warehouse operations by automating material handling tasks, reducing dependency on manual labour, and improving process consistency[3], [4]

Despite the promise of AMRs, successful implementation in warehouse environments hinges not only on technological capabilities but also on employee acceptance[5]. Past research underscores that resistance to technology adoption can undermine even the most well-planned investments, especially when employees perceive automation as a threat to job security or lack the necessary support from their organizations. In developing markets, these challenges are compounded by factors such as limited awareness of advanced automation solutions, varying workforce education levels, and differing perceptions of technology usefulness[6], [7]. Therefore, understanding the determinants influencing warehouse employees' acceptance of AMRs is critical to ensuring a smooth integration of this technology and realizing its full operational benefits.

The problem addressed in this study focuses on the limited empirical evidence regarding employee acceptance of AMRs in warehouse settings in Southeast Asia. While studies have explored technological and operational benefits of AMRs , there remains a scarcity of research investigating behavioural factors influencing their adoption among warehouse staff[8] This research gap hampers organizations aiming to design effective change management strategies and training programs tailored to employee concerns. Without addressing these human-centric factors, investments in AMRs risk underutilization or even outright rejection by key warehouse personnel.

The objectives of this research are:

RO1: To identify the key factors influencing warehouse employees' behavioural intention to accept and use AMRs.
RO2: To examine the relationships between performance expectancy, effort expectancy, social influence, and facilitating conditions with behavioural intention.

Based on these objectives, the research seeks to answer the following questions:

RQ1: What are the significant predictors of warehouse employees' behavioural intention to adopt AMRs?
RQ2: How do performance expectancy, effort expectancy, social influence, and facilitating conditions impact behavioural intention?

This study is significant for both academic and practical reasons. Academically, it contributes to the limited body of knowledge on technology acceptance in the context of warehouse automation, particularly in emerging economies [6]. Practically, it offers insights for warehouse managers and decision-makers on factors to prioritize when implementing AMRs, such as providing adequate training, addressing employee concerns, and ensuring organizational support [7]. These insights are crucial to fostering a positive attitude towards automation and maximizing return on investment.

2. LITERATURE REVIEW

Autonomous Mobile Robots (AMRs) represent a significant advancement in warehouse automation, enabling flexible and efficient material transport without reliance on fixed infrastructure such as conveyor belts or guided tracks. Studies have shown that AMRs improve productivity, reduce labour costs, and increase safety by minimizing human involvement in repetitive or hazardous tasks. However, while the technical benefits of AMRs are well documented, there is comparatively less research on the human factors affecting their adoption, especially in the context of emerging markets [3], [9], [10].

The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) have been widely applied to investigate user acceptance of new technologies across various industries. UTAUT, in particular, integrates multiple acceptance models and posits that performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) are the primary determinants of behavioural intention (BI) to adopt technology. These constructs have been validated in numerous contexts, including healthcare, banking, and education, but their application to warehouse automation with AMRs remains underexplored [5], [8].

Performance expectancy reflects employees' beliefs that using AMRs will enhance job performance. Past research highlights PE as the strongest predictor of BI in technology adoption studies. In warehouse settings, employees may associate AMRs with faster picking, reduced walking distances, and fewer manual errors, leading to higher productivity expectations. Field observations from the studied pharmacy warehouse revealed that AMRs reduced the average picking time for fast-moving stock-keeping units (SKUs) by approximately 30%, allowing staff to fulfil online and retail store orders more efficiently. Workers also noted fewer errors in order accuracy when collaborating with AMRs, reinforcing perceived performance gains.

Effort expectancy relates to perceived ease of use; if employees believe AMRs are intuitive and require minimal learning, their intention to adopt them increases. In the case warehouse, new full-time staff received on-the-job training lasting less than two days before independently operating the AMRs, which aligns with the principle that low perceived complexity boosts acceptance. Conversely, interviews indicated that part-time workers, who were excluded from AMR tasks, expressed apprehension about potential reassignments and unfamiliarity with AMR workflows highlighting the importance of inclusive training programs.

Social influence, defined as the degree to which employees perceive that important others (e.g., supervisors or colleagues) think they should use AMRs, can either encourage or discourage adoption. Interviews revealed that endorsement from warehouse supervisors was instrumental in shaping positive attitudes towards AMRs. Workers described how supervisors' daily encouragement and visible support of AMR integration fostered a sense of shared purpose, motivating employees to adapt.

Facilitating conditions refer to the organizational and technical infrastructure supporting AMR usage, such as training, maintenance, and communication of benefits. In the studied case, the warehouse implemented clear workflows for robot charging, route troubleshooting, and escalation processes in case of AMR faults. These support mechanisms significantly reduced staff anxiety and improved operational stability, reinforcing the role of FC in successful adoption.

Complementing UTAUT, the Supply Chain Agility and Resilience (SCAR) framework highlights organizational capabilities crucial for coping with disruptions and adapting to changing market conditions. Supply chain agility refers to the ability of an organization to sense, respond, and adapt quickly to environmental changes, including sudden shifts in demand or supply uncertainties. Resilience, on the other hand, focuses on a supply chain's capacity to absorb shocks and recover from disruptive events, such as pandemics or geopolitical instability.

During the COVID-19 pandemic, the case warehouse leveraged AMRs to maintain fulfilment rates despite severe manpower shortages due to quarantine protocols. The robots enabled continued operations with fewer staff on-site, demonstrating both agility through fast adjustments to shifting order volumes and resilience by ensuring service continuity despite workforce disruptions [1], [2].

Scholars have emphasized that automation technologies like AMRs can enhance both agility and resilience by increasing operational flexibility, reducing lead times, and maintaining service levels during crises[1], [11] The studied warehouse's experience aligns with these

findings, as managers credited AMRs for allowing the company to absorb pandemic-related shocks more effectively than competitors relying solely on manual processes.

Integrating SCAR with UTAUT provides a holistic perspective: while UTAUT addresses individual behavioural factors affecting AMR acceptance, SCAR underscores the strategic importance of AMRs in building agile and resilient supply chains. This dual-framework approach recognizes that employee acceptance of AMRs is not solely a matter of personal perceptions but also depends on how well AMRs contribute to organizational objectives of responsiveness and robustness in the face of disruptions.

Overall, existing literature supports the applicability of UTAUT constructs in predicting technology acceptance and validates the role of AMRs in strengthening supply chain agility and resilience. However, there remains a paucity of empirical studies applying these frameworks to AMR adoption in warehouse operations within emerging markets. This gap underscores the need for research combining established behavioural theories with supply chain management perspectives to inform successful AMR implementation strategies.

3. METHODOLOGY

This study employed a quantitative case study approach to investigate factors influencing warehouse employees' acceptance of Autonomous Mobile Robots (AMRs). The Unified Theory of Acceptance and Use of Technology (UTAUT) and the Supply Chain Agility and Resilience (SCAR) frameworks informed the research design[1], [8]. Data collection was conducted through a structured questionnaire targeting full-time employees directly engaged in AMR operations at the case warehouse[12], [13].

The survey instrument was developed based on validated UTAUT scales , with items measuring performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC), and behavioural intention (BI). Items were adapted to the warehouse context, using a five-point Likert scale ranging from strongly disagree to strongly agree. A pilot test involving five warehouse staff was conducted to assess the questionnaire's clarity, reliability, and relevance[14], [15]. Feedback from the pilot revealed confusion over certain Social Influence (SI) items; employees indicated that AMR usage was mandated by management, leaving little room for peer or supervisor persuasion. Social Influence (SI) was excluded from the final analysis, as AMR usage was mandatory and employees reported little to no peer or supervisor influence on their intention to use the technology. However, this may not be the case in settings where adoption is voluntary, and SI could play a more substantial role in influencing behavioural intention.

The target population comprised the 18 full-time warehouse employees who actively operated AMRs in their daily tasks, along with managers, supervisors, and technical personnel overseeing the AMR zone. The managerial group included director and warehouse managers, while supervisors consisted of team leads assigned to monitor daily productivity. Additionally, the technical personnel tasked with performing software updates, troubleshooting and maintaining the network infrastructure. Bringing the total respondent pool to approximately 30 individuals. This diverse yet focused respondent pool was chosen because it represented the complete census of staff directly engaged in AMR operations, capturing perspectives from frontline users to operational oversight and technical maintenance, thereby ensuring comprehensive coverage of those with firsthand experience.

Part-time and ad hoc staff were deliberately excluded from the sampling frame. Interviews with management revealed that these workers were assigned exclusively to packing and did not receive AMR training or exposure. Including them would introduce noise, as they lacked direct experience with AMRs, could distort the analysis of factors influencing acceptance. By

limiting participation to staff familiar with AMR workflows, the study ensured data validity and alignment with the research objectives.

Survey distribution occurred over one week during pre-shift meetings. Participation was voluntary, with assurances of confidentiality to encourage honest responses. Data were analysed using descriptive statistics, reliability analysis (Cronbach's alpha), and multiple linear regression to identify significant predictors of behavioural intention[12]. These methods allowed for rigorous examination of the relationships proposed in the research objectives, while ensuring robustness despite the modest sample size. Data analysis was conducted using IBM SPSS Statistics 30 and NVivo 15.

4. RESULTS AND DISCUSSION

A total of 30 valid responses were collected from full-time warehouse employees, managers, supervisors, and technical personnel directly involved with AMR operations, achieving a 100% response rate from the targeted respondent pool. Demographic data showed a workforce primarily composed of female employees, with most participants between 26 and 40 years old and possessing secondary or diploma-level education a profile typical of warehouse staff in the local industry.

Reliability analysis confirmed excellent internal consistency across the survey constructs, with an overall Cronbach's alpha of 0.940, indicating strong reliability of the measurement instrument. This suggests the questionnaire effectively captured employees' perceptions related to AMR acceptance.

Descriptive statistics revealed that performance expectancy (PE) and facilitating conditions (FC) were rated highly by respondents, with many agreeing that AMRs improved productivity and that the organization provided adequate support for using the technology. Among the facilitating conditions items, FC3 which measured employees' perception of the organization's economic support or incentives for adopting AMRs received the highest mean score within the FC construct, with a mean of 4.43 and a standard deviation of 0.63, indicating strong agreement that the company's willingness to invest in AMRs and provide financial or material resources played a decisive role in employee acceptance. Field interviews reinforced this finding, with several respondents emphasizing that seeing management's effort for AMR training, maintenance, fostering trust in the company's commitment to automation.

Quantitative operational data revealed a significant improvement in picking accuracy, which increased from 94% before AMR deployment (600 errors per 10,000 orders) to 99.95% after implementation, reducing errors to just 5 per 10,000 orders. This significant enhancement in accuracy reduced costly mistakes and improved customer satisfaction. At the same time, before AMR implementation, the "loose pick" zone was separated into outlets fulfilment and e-commerce sub-warehouse required 36 staff during normal operations and up to 54 staff (including part-timers) during peak periods. After AMR deployment, only 18 staff were needed during normal days and 24 during peak periods. This represents a 50% reduction in manpower requirements during normal operations, and approximately 56% during peak periods, while still achieving campaign fulfilment targets and enabling staff reallocation to higher-value tasks like campaign-specific order customisation, customer care, or transfer to different departments to assist with administrative work.

Additionally, AMR integration led to a 30.7% increase in inventory value within the same physical warehouse footprint, with total value rising from RM 9.11 million to RM 11.9 million after implementation. This increase was achieved by optimizing vertical storage space and reducing aisle width requirements, which allowed for higher-density storage without expanding the facility footprint. During campaign periods, throughput performance improved significantly, with the warehouse processing up to 22,000 order lines daily nearly double the

typical off-peak volume. These results suggest that AMRs can act as scalable, labour-efficient solutions when paired with reliable digital infrastructure and a well-planned operational redesign.

Multiple linear regression analysis indicated that both performance expectancy (β=0.383, p=0.044) and facilitating conditions (β=0.406, p=0.032) were significant predictors of employees' behavioural intention (BI) to use AMRs, while effort expectancy (β=0.244, p=0.211) was not statistically significant. The regression model demonstrated high explanatory power, with an R^2 value of 0.739, meaning that the included constructs accounted for approximately 74% of the variance in BI. These findings highlight that employees' belief in the productivity benefits of AMRs and the support provided by the organization were the most critical factors influencing their intention to adopt the technology.

Qualitative insights from staff interviews supported the quantitative findings, highlighting that AMRs reduced physical strain by minimizing walking distances and structured workflows, improving consistency and predictability of daily operations. However, interviews also revealed critical dependencies on backend systems: fulfilment continuity was found to be vulnerable to Wi-Fi signal drops below -50 dBm, which caused temporary loss of communication between the AMRs and the warehouse management system, leading to interruptions or rack misplacement. Additionally, inaccuracies in SKU metadata, such as mismatches between digital records and actual product dimensions or weights, were identified as sources of rack failures or AMR task errors.

Independent t-tests comparing BI across gender and education subgroups showed no statistically significant differences ($p>0.05$), suggesting that these demographic factors did not affect employees' acceptance of AMRs. This aligns with field observations, where acceptance levels appeared consistent among staff regardless of their gender or educational background.

Overall, these results support the first research objective (RO1) by identifying performance expectancy and facilitating conditions as the key factors influencing AMR acceptance. They also address the second research question (RQ2) by confirming that, in this warehouse context, effort expectancy was not a decisive predictor. The absence of significant effects from social influence, previously dropped during the pilot test due to lack of variance, was further supported by the regression model's strong performance without SI included.

5. DISCUSSION AND CONCLUSION

This study set out to investigate the factors influencing warehouse employees' acceptance of Autonomous Mobile Robots (AMRs) by integrating the UTAUT framework with supply chain agility and resilience (SCAR) perspectives. The findings confirmed that performance expectancy (PE) and facilitating conditions (FC) significantly predicted behavioural intention (BI) to use AMRs, while effort expectancy (EE) did not show a significant effect. These results suggest that in environments where AMRs are introduced with clear productivity benefits and robust organizational support, employees are more willing to accept and engage with the technology.

The dramatic increase in picking accuracy from 94% to 99.95% demonstrates the tangible benefits of AMR adoption. Alongside a 50% reduction in peak manpower requirements and a 30.7% increase in inventory value stored, these improvements highlight AMRs' potential to enhance both operational efficiency and warehouse capacity. These outcomes also support SCAR's assertion that automation can improve supply chain agility by enabling faster and more accurate responses to demand fluctuations, and resilience by maintaining high performance during peak periods.

Although prior studies have found effort expectancy (EE) to be a significant predictor of technology acceptance, in this case study, however, EE was not a significant factor influencing

behavioural intention. This can be attributed to the fact that AMRs had already been implemented for more than 12 months at the time of the study, by which point all employees had become familiar with the system and found it straightforward to use. As a result, there was very little variability in EE responses, making it less relevant as a driver of acceptance in this context. This suggests that, when a technology has been well established and universally adopted in daily operations, EE may become a baseline or 'hygiene factor' rather than a differentiating influence on behavioural intention.

Qualitative insights provided important nuances to these quantitative findings. Staff interviews revealed widespread appreciation for AMRs' ability to reduce physical strain and structure workflows, fostering more consistent and predictable daily routines. However, they also exposed critical dependencies on digital infrastructure: fulfilment continuity was sensitive to Wi-Fi signal quality and the accuracy of SKU metadata, both of which could cause system errors or rack failures. These challenges highlight the need for comprehensive operational redesigns when integrating AMRs, ensuring that supporting systems are robust enough to match the robots' capabilities.

While this research contributes to the limited empirical literature on AMR acceptance in Southeast Asian warehouse contexts by confirming that performance expectancy and facilitating conditions are decisive factors, there are notable limitations. First, a detailed cost-benefit analysis could not be performed, so the return on investment (ROI) of AMR implementation remains unquantified. Second, as this study focused on a single case example, the generalisability of the findings may be limited. Future studies should examine a broader range of settings to strengthen external validity

The results of this study offer clear guidance for warehouse operators, supply chain managers, and technology vendors aiming to deploy AMRs effectively in similar contexts. First, the strong influence of performance expectancy underscores the importance of quantifying and communicating clear productivity improvements when introducing AMRs; detailed metrics like error reduction and manpower savings can motivate both management and employees to support adoption. Second, the significance of facilitating conditions highlights that investment should not stop at robot procurement; comprehensive training, visible management commitment, and stable technical infrastructure are critical to sustaining AMR performance and employee confidence.

The demonstrated increase in inventory value stored and improved order throughput illustrates how AMRs can enable higher warehouse density and responsiveness without expanding facility footprints, a crucial advantage in urban or high-rent areas. However, the vulnerabilities identified including dependencies on accurate SKU metadata and stable backend connectivity serve as reminders that AMRs should be integrated within a broader digital ecosystem designed for reliability. Organizations seeking to maximize the scalability of AMRs should prioritize rigorous data governance and IT resilience alongside physical robot deployment. Overall, these insights suggest that successful AMR implementation is as much about organizational readiness and process redesign as it is about the robots themselves.

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