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Warehouse Automation Implementation Environment: Case of Central Warehouse Management in Mali, West Africa

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Abstract
The implementation of warehouse automation has proven to be an effective way to increase productivity and inventory accuracy, lower labor costs, and improve safety in the warehouse environment. This research aims to investigate the factors contributing to the success of warehouse automation implementation. This study offers a unique and modern warehouse automation environment model as a solution for complete implementation in warehouse automation operations. The study was conducted in Mali, West Africa. A total of 100 responses were collected among warehouse managers through an online Microsoft Forms survey. Smart PLS version 4.0 software was used to analyze the data.

Keywords: Automation, Environment, Implementation, Warehouse

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1.0 Introduction

Leading businesses and organizations are working hard to make their warehouses more responsive, resilient, and dependable to maintain the rapidly growing e-commerce market in supply chain automation. In West Africa, the most common issue is limited warehouse automation. Hence, automating processes within a warehouse is vital to ensuring smooth and efficient operations. Due to the high demands of the supply chain industry, warehouse automation in West Africa has become increasingly important. One of the main targets is to eliminate or reduce the likelihood that this has significantly impacted warehouse employee services, leading to the failure of warehousing automation implementation. The influence of warehouse automation implementation is empirically unclear yet being investigated, particularly in West Africa. Thus, this study aims to determine the critical success factors for implementing warehouse automation. With the right technology (Karpova, 2022), it is expected to assist users in utilizing available tools and submitting the required information at the appropriate location, time, and cost (Olalere, 2022). Warehouse employees and organizations are at the heart of this

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study, which intends to improve employee and organizational capacity and benefit society and people through technology to improve the automation implementation environment.

2.0 Literature Review

2.1 Definition of Warehouse Automation

Warehouse automation incorporates technology and machinery to streamline warehouse management (He et al., 2023). This includes automating inventory management, order fulfillment, shipping, and receiving (Sharma, 2023). Improves warehousing and cargo delivery services for customer satisfaction by promoting automated, efficient operations. (Adenigbo, et al., 2023). As illustrated in Fig. 1, the experts predicted the market would reach more than $23 billion in 2023 and increase at a CAGR of about 15%, reaching 41 billion US dollars in 2027 (Statista, 2023). Observing how companies adapt to this shift in the industry will be interesting (Soni et al., 2022).

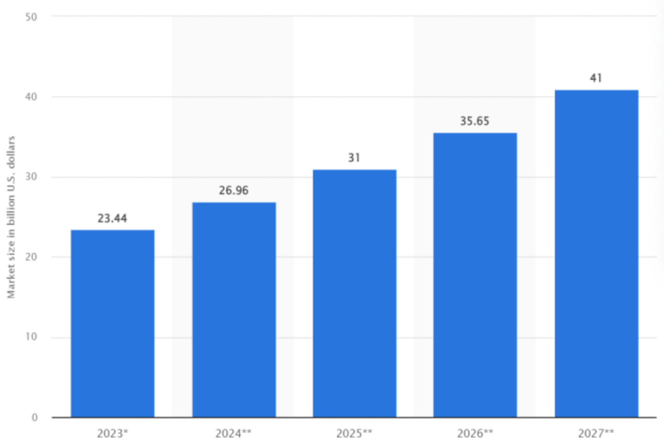

Fig. 1: Global warehouse automation market size 2023-2027
Source: Statista (2023)

2.2 Productivity

When it comes to achieving goals, productivity is critical. Productivity is defined as the ratio of multiple outputs to a single input. Productivity is a topic that has been debated for many years, and there is currently a growing interest in productivity in terms of performance measurement (Karim et al., 2021). To accomplish more and reach our goals faster, we can work smarter, not more complexly, and achieve more in less time (Fauzi et al., 2023).

2.2 Accuracy

Accuracy is crucial for determining a measurement's reliability. It measures the level of closeness between an estimated value and the actual value, and it can be expressed as a percentage or a ratio (Baid et al., 2023). Maintaining accuracy requires employees to be conscious of the consistency of their work process. This helps to ensure the number of unlocated locations (Arasu,2022).

2.3 Safety

In warehouse operations, we must always take precautions and measures to protect ourselves from harm or danger (Lin et al., 2022). It is a management guide that explains how to deal with hazards on the job and recommends the specified workplace safety standards for the employee. (Đurđević et al.,2022).

2.4 Cost

The cost of warehouse automation can vary depending on an organization's specific needs and requirements (Fatima et al., 2022). Additionally, there may be expenses associated with training employees on the new technology and potential downtime during the implementation process (Basaldúa & Cruz Di Palma, 2023). The cost of warehouse automation is the money required to implement it successfully. Based on the Fig.2 The barriers spread: cost remained the top barrier (44%), and Implementation complexity was 39%.

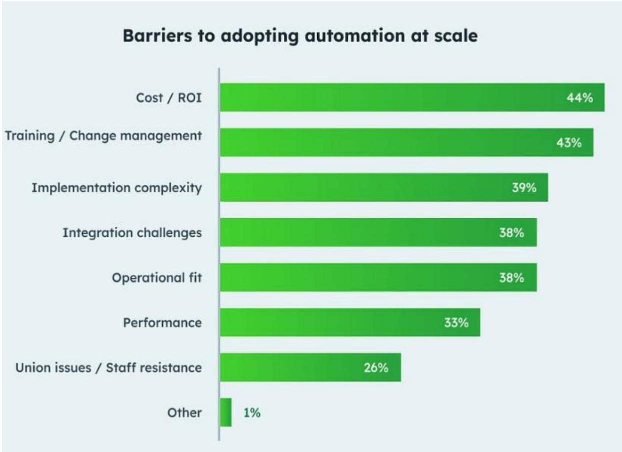

Fig. 2 Barriers to adopting automation.
Source: Vecnarobotics (2023)

2.5 Familiarity
The warehouse has lost its structure over the years, so it now relies on the employee's familiarity with the business and its many moving parts to function correctly (Mohamud et al., 2023). Evaluation of familiarity can provide a relatively accurate metric for system performance and lead to a more comprehensive return on investment (ROI) analysis (Pandey et al., 2023).

3.0 Methodology
This study uses a quantitative approach (Sham et al., 2022). The respondents were selected among the warehouse managers who deployed in different parts of regional warehouses through an online Microsoft Forms survey. The 100 respondents were selected based on the statistics of international organizations referring to the targeted population of five hundred warehouse employees from the international organization according to supply chain records (2023). The study proceeds with a self-administered questionnaire (Co & Baldovino, 2023) adopted using Smart PLS4 as a previous researcher who surveyed warehouse automation in the UK (Adamczak et al.,2022).

3.1 Variable Measurement and Questionnaire Design
After a comprehensive literature review, 13 key constructs fall into six variable categories. These findings result from a thorough literature review and analysis of the automation environment 1. WAE, an independent variable. 2. PROD is the first dependent variable 3. ACC, the second dependent variable 4. SAFE, the third dependent variable 5. FAM, the fourth dependent variable; and 6. CT, a mediating variable. A self-administered questionnaire was utilized during the data collection to gather information from the target respondents (Co & Baldovino, 2023), and online data via Microsoft Forms with a 5-point Likert scale was used to provide the respondent with a clear indication of the intensity. All constructed measurement items range from 1" strongly disagree to 5 strongly agree. The measurement of the construct was as follows:

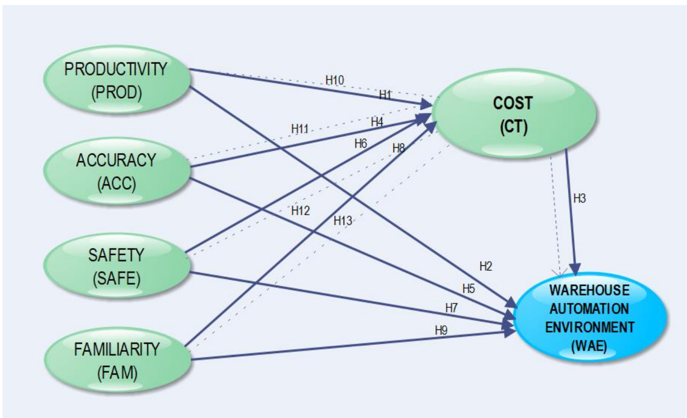

Fig. 3 Research Framework

4.0 Findings

4.1 Demographic profile of Respondent results

The demographic profile of respondents was primarily analyzed by Power BI software. The result is based on age, gender, educational background, nationality, length of experience, and rank (Co & Baldovino). Based on the Power BI results of the respondent's nationality, the highest number of respondents is from other countries, with 37 warehouse managers, or about 37%, and the lowest is from Mali, with 1% of warehouse managers. Concerning gender, the highest rate of responders is male, with 57 warehouse managers at 57%. The lowest is a volunteer, with one warehouse manager at 1%. According to age, the highest respondent is 51–60 years old, with 81 warehouse managers (81%), and the lowest is 61–65 years old, with eight warehouse managers (8%). Regarding experience, the highest rate of responders is 10–15 years, with 39 warehouse managers at 39%. The lowest is 0–5 years, with two warehouse managers at 2%. Regarding rank, field service 1-6 has the highest rate of responders (39%), with 84 warehouse managers. The lowest level is one volunteer at 1%. In terms of education, bachelor's degrees were obtained by 89% of the 89 warehouse managers polled. The lowest is a master's degree, with 11 warehouse managers accounting for 11% of the total.

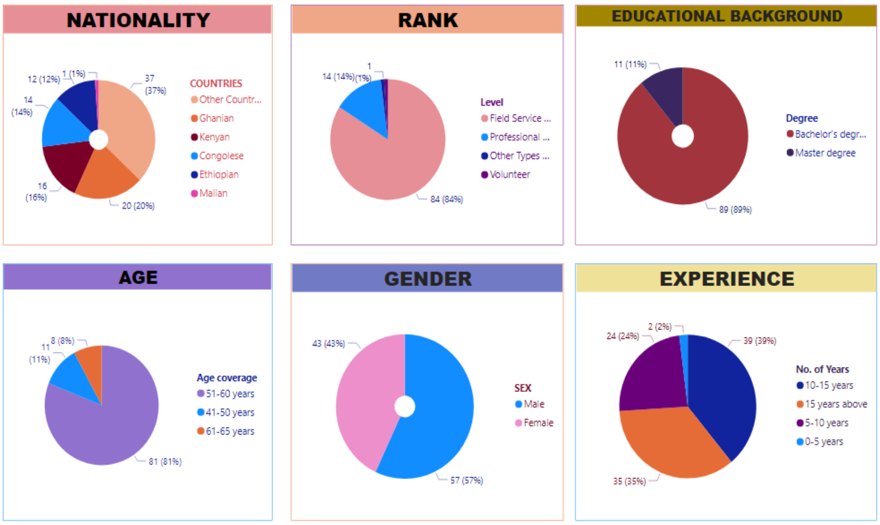

Fig 3. Demographic profile of respondents

4.2 Primary Analysis

The primary analysis used Power BI (Pollock et al., 2023) to calculate the demographic profile of respondents. A preliminary analysis was performed before testing the construct's reliability and validity. Demographic data are used in the preliminary analysis. During preliminary analysis, it was discovered that the data contained all values. Following that, the demographic analysis was investigated using Microsoft Power BI software. Power BI is an excellent tool for visually and interactively presenting data.

4.3 Factor Loading

The factor loading of an item indicates how well it represents the underlying construct. The factor loadings of this study are greater than 0.70 and are usually recommended (Hair et al., 2019).

4.4 Measurement Model Analysis

Based on the findings of our study, the indicator's outer loadings are higher than 0.70, as recommended by Hair et al. (2019). We used measurement model analysis to assess the outer model's construct validity, reliability, and discriminant validity, employing the PLS algorithm. This study used composite reliability (CR) and Cronbach's alpha (CA) to evaluate the construct's validity and reliability. Across all constructs in this study, the CR ranged from 0.801 to 0.868. The measurement model's construct was reliable, with CA values ranging from 0.687 to 0.778, beyond the suggested value of 0.7. The Fornell-Larcker criterion, cross-loading matrix, and HTMT results all support the discriminant validity of the data.

Table 1. Measurement model-quality criteria

Construct	Items	Loadings	CA	CR	AVE.
Productivity	PROD 1	0.711	0.733	0.850	0.755
	PROD 2	0.839			
	PROD 3	0.870			
Accuracy	ACC1	0.819	0.712	0.838	0.733
	ACC2	0.821			
	ACC3	0.745			
Safety	SAFE1	0.917	0.778	0.868	0.789
	SAFE2	0.843			
	SAFE3	0.716			
Familiarity	FAM1	0.789	0.768	0.815	0.795
	FAM2	0.759			
	FAM3	0.767			
Cost	COST1	0.830	0.737	0.851	0.756
	COST2	0.830			

	COST3	0.767			
Warehouse Automation Environment	WAE1	0.832	0.687	0.801	0.776
	WAE2	0.783			
	WAE3	0.650			

Validity is the soundness or appropriateness of the instrument measuring what it is designed to measure (Fuller et al., 2020). The degree to which a measure produces the same results when applied in the same circumstances is called its reliability (Rose et al., 2020). Convergent Validity is within the construct and how the items are converging in the construct (Fuller et al., 2020). The indicators of the specific construct should converge or share a high proportion of variance. The average may be used as a convergent or divergent validity test. In a reflective model, the average reflects the average communality for each latent factor. AVE should be greater than 0.5 in an adequate model (Sihombing & Arsani, 2022) and more significant than the cross-loadings, implying that factors should explain at least half of their respective indicators' variance.

Table 2. Discriminant Validity (HTMT)

	PROD	ACC	SAFE	COST	FAM	WAE
PROD						
ACC	0.876					
SAFE	0.816	0.857				
COST	0.805	0.838	0.841			
FAM	0.755	0.737	0.887	0.753		
WAE	0.595	0.507	0.665	0.489	0.739	

The heterotrait-monotrait ratio of correlations (HTMT) analysis was used to determine discriminant validity. Table 2. shows the model summary of HTMT, showing the strong relationship between the IV and DV. The heterotrait-monotrait ratio (HTMT) was below 0.9, which is a satisfactory HTMT.

Table 3 shows that the difference between the model's implied correlation matrix and the empirical correlation matrix should be non-significant ($p > 0.05$). Model fit is not established if the difference is significant ($p < 0.05$).

Table 3. Summary of Hypothesis Test and Moderating Effect Analysis

Effect	Hypothesis	B value	T value	P value	Decision
Direct	H1	-0.282	2.596	0.005	Accepted
Direct	H2	-0.038	0.561	0.287	Rejected
Direct	H3	0.611	5.570	0.000	Accepted
Direct	H4	0.764	6.216	0.000	Accepted
Direct	H5	0.221	1.801	0.036	Accepted
Direct	H6	-0.024	0.395	0.346	Rejected
Direct	H7	-0.247	1.547	0.021	Accepted
Direct	H8	0.533	3.892	0.000	Accepted
Direct	H9	0.404	2.186	0.014	Accepted
Mediating	H10	0.207	1.458	0.073	Rejected
Mediating	H11	-0.132	1.290	0.009	Accepted
Mediating	H12	-0.155	1.256	0.005	Accepted
Mediating	H13	0.051	1.084	0.139	Rejected

4.5 Structural model analysis

Hair et al. (2014) state that four essential criteria exist for evaluating the structural model analysis in PLS-SEM. The significance of path coefficients, effect size (f2), coefficient determination (R2), and predictive relevance (Q2)
are among these criteria (Hair et al., 2022). The path coefficient significance evaluation results are shown in Table 3 and Fig. 4, which can be used to evaluate the model's overall performance. Considering these criteria when evaluating the structural model to ensure its accuracy and reliability (Hair et al., 2019) is critical.

4.6 Construct Validity Calculation

Construct validity = convergence coefficient - discriminant coefficient.

The correlation coefficients between the assessment results and other similar assessments should be calculated to quantify convergent validity.

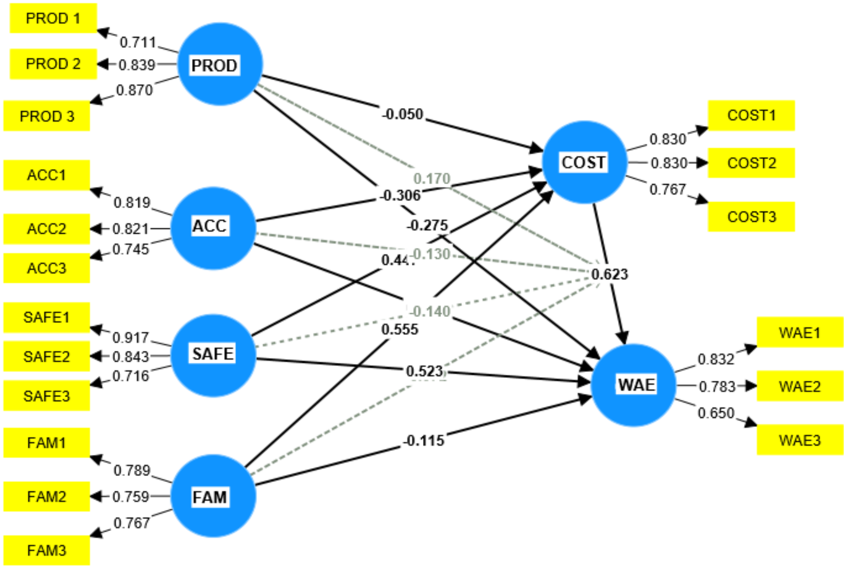

Fig. 4 Structural Model Analysis

4.7 PLS-SEM Algorithm

The PLS algorithm produces the following overall result: The X components are used to predict the Y component scores, and the predicted Y component scores are used to predict the measured Y variables. While the original X variables may have been multicollinear, the orthogonality of the X components used to predict Y is guaranteed. Furthermore, the X variables may contain missing values, but each case on each X component will have a computed score. Finally, because only a few components (usually two or three) are used in predictions, PLS coefficients can be computed even if there are more original X variables than observations (though results are more reliable with more cases). In contrast, any of these three conditions (multicollinearity, missing values, and a small number of cases concerning the number of variables) may make traditional OLS regression estimates unreliable or impossible. The same is true for estimates from other procedures in the families of general and generalized linear models.

5.0 Discussion

The relationship of productivity, familiarity, and accuracy to cost was significant and positive; however, safety to cost was insignificant and had a negative effect on the warehouse automation implementation. It was also observed that familiarity and productivity to cost have mediating effects on the warehouse automation implementation. As a result, the study discovered that productivity, familiarity, and accuracy have an extensive contribution to the implementation. However, safety is not a 100% guarantee of successful implementation since critical success factors identify the weaknesses of internet connectivity during the automation implementation process. A warehouse automation environment assessment is critical since it infers the demand for warehouse automation safety, accuracy, reliability, and efficient services. This study's findings are consistent with the warehouse automation implementation environment described by Lee et al. (2022), who stated that implementing automation is a critical success factor However, there are some barriers that we need to consider. Potential benefits include robust internet connectivity, employee relief, improved operational efficiency, and quality. Organizational readiness is defined by Kosmol et al. (2019) as the managerial and contextual prerequisites for implementing new digital technologies. Building smart warehouse automation is a critical task, reinforcing learning methods to train a sustainable warehouse environment for an efficient inventory policy.

6.0 Conclusion & Recommendations

The study has addressed the two main factors safety and cost influencing the warehouse automation environment, thus creating limitations over other variables that might influence the warehouse automation implementation. The study has implications for warehouse managers in the decision-making process and procedures, particularly in the warehouse industry in Mali West Africa. Given the complexity of supply chain networks associated with downstream processes, a risk assessment should be included in future research to understand the situation better.

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Paper Contribution to Related Field of Study

The study contributes to the body of knowledge of the supply chain pool, where the findings are used to examine the warehouse automation environment's critical success factor. The findings would also raise awareness of warehouse industry activities and warehouse managers, allowing them to improve strategies and disseminate information about the success or failure of warehouse automation for future and better practices among the industry players in the supply chain industry in West Africa.

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