ENHANCING LOGISTICS OPERATIONS THROUGH OPTIMAL WAREHOUSING DESIGN

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Abstract

Warehousing plays a vital role in sustaining global supply chains. This study examined the effect of warehouse design optimization on the logistics operational performance of the Nairobi Inland Container Depot, Kenya, with a specific objective to ascertain the effects of equipment layout on logistics operational performance. The study is grounded in systems theory. It employed a correlational design and conducted a census. Respondents were drawn from the warehousing management, transportation management, and customer care departments. Data was analyzed using descriptive and inferential statistics. The overall model was interpreted using F-value results; the F-statistic was 3.2 against a critical F-value of 2.67. Results showed that equipment layout significantly influences the logistics operations of the Nairobi Inland Container Depot. Future studies should use surveys to examine warehouse optimization and map all containers as part of reverse logistics to assess performance of port activities in Kenya.

Keywords: Warehouse Optimization, Equipment Layout, Logistics Operations Performance, Inland Container Depot.

Introduction

Fundamental to modern supply chain management operations is warehousing located at inland container depots (ICDs), also referred to as dry ports, which handle and store containerized cargo temporarily [1]. These ports aid hinterland customers by providing port services closer to their premises [2]. These ports play a significant role in the success or failure of many global businesses today [3]. These entities: (i) provide storage for raw materials, components, work-in-process, and finished goods; (ii) operate as distribution and order execution centers; and (iii) perform localized and value-added warehousing [4]. The tasks of inland container depots include reception, storage, picking, loading and unloading, and shipping [5]. Similarly, these depots manage inventory levels, track product movement, and optimize warehouse layout operations to reduce costs and improve customer satisfaction [6]. Effective warehouse management ensures efficient flow of goods and materials through supply chains from the point of receipt to the point of delivery [3]. The number of containers handled at container terminals has increased significantly [7]. Numerous changes must be made to layouts to accommodate and handle the increasing number of containers entering and leaving container terminals [8]. The transfer of containers between landside and seaside requires new layouts with smaller footprints that are faster, cheaper, and more efficient [8].

According to a World Bank report, Kenya's logistics performance is rated best in East Africa due to the continued reduction of administrative controls and the upgrading of infrastructure [7]. Similarly, according to logistics performance indicators (LPI), Kenya ranked 42nd globally with a score of 3.33 points in 2019, while surveys conducted in 2019 placed Uganda and Tanzania at 58th and 61st positions with scores of 3.04 and 2.99, respectively [7]. Kenya's logistics performance is second on the African continent after South Africa, which is in the 20th position globally with a score of 3.78 [9]. This LPI shows that Kenya has significantly reduced the costs of doing business and improved its trade flow for exporters and importers, as the attractiveness of a country's logistics depends on customs clearance efficiency and effectiveness [7]. Optimized layout setups are aligned to meeting business operational needs and integrate warehouse design by revolutionizing inventory organization and retrieval, ensuring swift and accurate fulfillment [2].

Statement of Problem

Warehouse design requirements vary based on factors such as regional infrastructure, economic development, and trade patterns [5]. Inland container depots (ICDs) serve as critical nodes in logistics networks, connecting ports or airports to inland destinations [10]. Regional variations in market characteristics, consumer preferences, and supply chain dynamics influence the design and optimization of warehouses to cater for specific regional needs [11]. Factors such as availability of appropriate equipment, space layout, and the flow of in-transit inventory influence warehouse optimization [12]. Local market settings, customer demands, and industry practices affect the design and operational requirements of warehouses in ICDs [13].

Additionally, local culture and business settings may affect adoption of new technologies, workforce capabilities, and overall working efficiency [14]. Murugi (2022) [15] examined container terminal layouts, identifying different possible future developments and observed that mathematical optimization is more suitable for scheduling problems in the final steps of Netherlands firms. It also identified racks, lifts, transport tools, and automation as key components for handling containers. This study replicates Murugi's research by focusing on equipment layouts (racks, lifts, transport tools, and automation) and their effect on the logistics operational performance of ICD Nairobi, Kenya. Asha and Noor 2019 [16] examined the role of warehouse layout design on the performance of distribution at DHL, Kenya, using a descriptive research design. The study found that several basic principles apply to warehouse layout design and effective distribution center operations [17]. Elsewhere, a study on the impact of logistic management practices on the performance of operations by road transport companies in Jordan using a descriptive-analytical approach observed that logistic management practices influence inventory management, warehousing, order processing, transportation, and packaging on operational performance [18] and further identified a knowledge gap in the optimization of warehousing design layouts.

Null Hypothesis of the Study

This study tested the null hypothesis that equipment layouts have no significant effect on logistics operations performance of Nairobi ICD, Kenya.

Specific Objective of the Study

The specific objective of the study was to ascertain the effects of equipment layouts on logistics operational performance of Nairobi ICD, Kenya.

Significance of the Study

This study aimed to contribute to the existing knowledge of supply chain management, with a specific focus on warehouse optimization and its influence on the operational performance of inland container depots. The study sought to broaden an understanding of how warehouse optimization, particularly through equipment layouts, can enhance the operational logistics for organizations, thereby improving overall supply chain performance. The findings of this study can guide the development and implementation of policies aimed at creating resilient and efficient logistics supply chains.

Theoretical Review

Systems Theory

Systems theory is an interdisciplinary framework that examines the relationships and interactions between components within a complex system [1]. It emphasizes a holistic perspective, focusing on the whole system rather than just its parts. This theory offers a perspective on warehouse design optimization and its impact on overall logistics operations

[19]. It recognizes that warehouse design is an integral part of the broader logistics system and explores how optimizing it affects efficiency and effectiveness of the entire logistics system [20]. The study utilizes systems theory to examine how optimizing warehouse design impacts efficiency and effectiveness of the entire logistics system within ICDs in Kenya. This theory investigates how changes in equipment layouts, material flow, or storage systems affect other aspects of logistics operations [21]. A well-designed warehouse reduces material handling time, influencing inventory management and passage routes [20]. By analyzing these feedback loops, potential areas for improvement and optimization can be identified. Systems theory also acknowledges that a system possesses emergent properties, recognizing that the overall performance and outcomes of logistics operations within ICDs are influenced by the synergy and interaction of various elements, such as layout, technology, workforce, and processes [22]. Therefore, this study explores how optimizing warehouse design contributes to the emergence of desirable properties such as increased operational efficiency, reduced costs, improved customer satisfaction, and boundary spanning as the interactions and exchanges between the warehouse and its external environment [21].

Empirical Review

Equipment Layouts

The global logistics sector has undergone significant transformations due to technological advancements [23]. In the past, manual tasks were the norm, but now, automation has enhanced efficiency [24]. Previously, customers lacked visibility into the status of their cargo during transit, but today, advancements in software and internet technology have improved tracking systems [4]. Additionally, standardized procedures now guide the operation of forklifts in warehouse management systems, ensuring safety and efficiency [24].

A well-designed layout takes into account the smooth movement of people, equipment, and vehicles within the facility [25]. By establishing separate pathways for materials, employees, and vehicles, the potential for congestion and accidents can be significantly minimized [26]. In many instances, the planning of a warehouse begins not with the space itself, but with elements such as racks, lifts, or transport equipment, which need to be carefully considered and evaluated for their specific attributes [27]. Optimizing warehouse tasks encompasses various aspects of business management, including inventory management, organization, and transportation management [28]. This process involves making the most of the warehouse's available storage capacity and assessing the impact of material handling equipment choices, labor, methods, procedures, and support systems on warehouse operations [29]. Warehouse design and operations have undergone significant changes with the rise of e-commerce [29]. The complexity of warehouse operations has increased due to the storage of a wide range of stock-keeping units (SKUs) in small quantities, unpredictable demand patterns, and primarily single-line customer orders [30]. Warehouses have expanded in size due to consolidation, and new identification and communication technologies have been integrated, while process automation technologies have advanced, enhancing speed and operational efficiencies [29].

Equipment Layout on Logistics Operations Performance

Garehgozli et al 2019 [2] discussed different container terminal layouts and potential future developments. These developments include expansion by adding or reclaiming land, collaboration with inland terminals, construction of offshore containers, and movement of empty containers to external depots in the Netherlands. The review also presented innovative solutions such as container racks and overhead grid rail systems. The authors used a three-step framework, simulation, and queuing models to estimate performance during the first two steps of layout analysis and design optimization. They found that mathematical optimization is more suitable for addressing scheduling problems within the last steps [22]. Saderova et al 2014 [31] examined warehouse system design methodology by applying the logistics principle-systematic system approach in Slovakia in a cold box. The design process entailed numerous phases of project identification, design process, system analysis, synthesis, and project evaluation. The warehouse system was designed for two options of racking assemblies served by forklifts based on: alternative 1 and alternative 2 (standard pallet rack with wide aisles and pallet dynamic flow rack). These systems were compared based on capacity, the percentage ratio of storage area from the box area, the percentage ratio of handling aisles from the box area, access to individual pallets by forklift, and investment costs for 1 pallet space in EUR. Based on the multi-criteria evaluation, alternative 2 was chosen as the acceptable design of the warehouse system with a storage capacity of 720 pallet units. Loading and unloading processes are separate from each other, implying that there are no collisions with forklifts. The pallets with the goods are operated on the principle of FIFO (first in, first out), which facilitates the control of the shelf life of batches or series of products.

Odeyinka and Omoegun 2023 [23] examined various types of warehouses and analyzed activities involved in warehouse operations in Nigeria. The integration of warehouses into the supply chain process is emphasized in their critical role in facilitating the flow of goods. The study delves into WMS functions and highlights its importance in inventory control, order management, and system reliability by probing variances amid traditional manual warehousing and automated approaches by taking into account factors such as cost, efficiency, and suitability for different types of organizations. The study suggests that automated warehousing is more suitable for larger companies operating in countries with limited manual labor availability.

Murugi 2022 [7] examined the effect of the adoption of a single window system, cargo scanner management system, and electronic cargo tracking system on logistics performance. Resource advantage competition and task technology fit theories guided the study. It adopted an explanatory research design targeting 300 customs officers and managers of logistics companies within Nairobi. A sample of 171 customs officers and logistics managers were selected using a stratified random sampling technique. Results showed that single window systems, electronic cargo tracking management systems, and cargo scanner management solutions have a positive and significant effect on the logistics performance of transport operators.

Conceptual Framework

The conceptual model clarifies the affiliation between independent and dependent variables in the study. The independent variable is equipment, and the dependent variable is logistics operational performance, as presented on Figure 1. This was conceptually hypothesized as equipment layouts having no significant effect on the logistics operations performance of Nairobi ICD, Kenya.

[redacted]

H1

[redacted]

Independent variable

Dependent Variable

Figure 1: Conceptual Framework

Based on the study's objective and the literature reviewed, the conceptual hypothesis formulated was that equipment layout has a significant effect on the logistics operations performance of Nairobi ICD, Kenya.

Materials and Methods

Research Design

This study adopted objectivism, subjectivism, and interpretivism views of research According to Yin [31]. A descriptive research design is a scientific method considered best as it involves observing, describing, recording, analyzing, and reporting conditions that exist without alterations. Gitonga et al 2020 [14] described a case study as a description of a specific situation to understand processes performed within an organization. The case study aims to answer how the object affects and is affected by its surroundings. This study applied a descriptive case study design.

Population of the Study

Yin 2017 [31] Emphasizes that a target population refers to a sample from a defined population from which specific units have been properly selected. A population is a complete set of individuals, cases, or objects with some common observable characteristics.

A target population is the total number of respondents in the environment of interest to the researcher [32]. The study targeted managers and staff in warehousing management [7], transportation management [33], and customer sections [28]. The study was a census.

Instrumentation: Reliability and Validity

The data collection process involved a self-administered structured questionnaire. The validity and reliability of the instrument were established through various measures, including a pilot study, pre-test, expert opinion, and Cronbach Alpha coefficient. The Cronbach's Alpha coefficient indicated internal consistency, with acceptable values for equipment layout and logistics operations performance. Validity tests, including construct and face validity, were conducted. Statistical analysis, such as ANOVA, confirmatory factor analysis, correlation, multiple regression, and hierarchical regression, was used to establish relationships between variables. An alpha coefficient of .700 or above is an acceptable measure. Equipment layout had a Cronbach Alpha coefficient of .802 and logistics operations performance had .794. This indicates that the data collected using the aforementioned instrument was reliable for analysis.

Data Collection Procedures

Researchers obtained permission to collect data from the National Commission for Science, Technology, and Innovation (NACOSTI). After obtaining permission from the respective university, the drop-and-pick method was used, where the questionnaire was left with the respondents and picked up after it had been filled out.

Data Analysis and Presentation

The simple linear regression model used was: $Y=\beta 0+\beta 1X1+\varepsilon Y=\beta 0+\beta 1X1+\varepsilon$, where YY is logistics operations performance (dependent variable), $\beta 0\beta 0$ is the intercept, $\beta 1\beta 1$ is the coefficient, $X1X1$ is equipment layouts (independent variable), and $\varepsilon\varepsilon$ is the error term.

Ethical Considerations

The researchers obtained a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI) to undertake the study. Authority was also sought from and granted by the Technical University of Kenya.

Consent was obtained from respondents before data was collected and guaranteed the respondents' confidentiality of the information provided.

Findings and Discussion

The study used both descriptive and inferential statistics for data analysis. Regression analysis was used to establish the relationship between the variables and to test the hypothesized relationship. The coefficient of determination $R2R2$ shows the degree or amount of variation in the dependent variable attributed to the predictor variable. The Beta values show the amount of change in the dependent variable attributable to the amount of change in the predictor variable, and the F ratio measures the model fit, indicating how well the developed equation line fits with observed data. The statistical significance of each hypothesized relationship was interpreted based on $R2R2$, F, t, β, and p values.

Table 1a: Model summary, anova and regression analysis test results for equipment layout on logistics operational performance items.

Model	R	R- square	Adjusted R-square	Std. Error of the Estimate -	Durbin Watson
1	.175a	.031	.007	1.04811	1.832

a. Predictors: (Constant), Racks, Forklifts/cranes, Transport tools and Automation
b. Dependent variable: Logistics operational performance

Model		Sum of square	*df*	Mean square	F	Sig
Regression		2.644	4	.881	3.2	.001a
1	Residual	85.734	32	1.099		
Total		88.378	36			

a. Predictors: (Constant), Racks, Forklifts/cranes, Transport tools and Automation

b. Dependent variable: Component 1, Logistics operational performance

Model		Un-standardized Coefficients		Standardized Coefficients	t	Sig
		B	Std. Error	Beta		
	(Constant)	2.016	.432	4.672		.000
	Racks	-.157	.121	-.169	1.305	.001
1	Forklifts/cranes	.191	.138	.185	1.385	.007
	Transport tools	.349	.120	.339	2.918	.070
	Automation	.219	.340	.122	1.146	.001

Dependent variable: Component 1, Logistics operational performance

The Coefficient of determination and coefficient of correlation results on Table 1a are as follows: $R^2 = 0.031$, $R = 0.175$. These results imply that 3.1% of the variation in the dependent variable is explained by equipment layout, while the correlation between the independent and dependent variables is 17.5%. From these outputs, the F-test value (3.2) is higher than the critical F-value (2.67) [34]. The unstandardized values on Table 1b indicate that racks, forklifts/cranes, and automation significantly contribute to the dependent variable, whereas transport tools were insignificant. The analysis derived the following econometric regression equation:

$Y = 2.016 - 0.157X1 + 0.191X2 + 0.349X3 + 0.219X4$. Additionally, the R-value signifies a genuine but modest link with the criterion variable [33].

Conclusion and Recommendation

The objective of the study was to ascertain the impact of equipment layout on the logistics operational performance of the Nairobi Inland Container Depot (ICD), Kenya. The key indicators of the variable studied were racks, forklifts/cranes, transport tools, and automation. Descriptive statistics indicated that equipment layout had a significant effect on the response variable. Inferential statistics revealed that racks, automation, and forklifts/cranes had a substantial influence on the criterion variable, whereas transport tools had a negligible impact.

The coefficient estimate values are as follows: Beta = 2.016, coefficient of determination R^2 = 0.031, F-statistic = 3.2 and critical F-value = 2.67. These results indicate that the F-statistic (3.2) is higher than the critical F-value (2.67), signifying that the model is substantial. Consequently, the null hypothesis is rejected, and the alternative hypothesis is accepted.

Future Research

The study recommends that upcoming studies should encompass the mapping of all containers as reverse logistics to assess their impact on port activities in Kenya.

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