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Lean warehousing framework: Enhancing order fulfilment in food and beverage depots

Mohd Khidir Osman[1], Effendi Mohamad[2*], Nurhayati Kamarudin[3] , Arfauz A. Rahman[4], Teruaki Ito[5]
[1] Institute Technology and Entrepreneurship Management, Universiti Teknikal Malaysia Melaka, Malaysia
[2] Faculty of Industry and Manufacturing Technology and Engineering, Universiti Teknikal Malaysia Melaka, Malaysia
[3] Faculty Technology and Technoentrepreneurship Management, Universiti Teknikal Malaysia Melaka, Malaysia
[4]School of Mechanical and Aerospace Engineering, Queen's University Belfast, UK
[5]Faculty of Computer Science and Systems Engineering Okayama Prefectural University, Japan

*Corresponding author E-mail: effendi@utem.edu.my

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Abstract

This study aims to develop and validate an integrated lean warehousing framework to enhance order fulfilment performance in Malaysian food and beverage depots. The method used was an explanatory sequential mixed design, with quantitative data collection from 207 respondents across 15 selected depots, and a qualitative time study through observation of the warehousing process. Principal Component Factor Analysis (PCA) identified six operational components, revealing significant performance differences between inbound and outbound operations: outbound operations are well-performed, with 75-80% satisfaction, whereas inbound operations experienced critical bottlenecks, with 40-51% satisfaction. Correlation analysis revealed 3 significant factors that caused warehousing inefficiency and affected order fulfilment: information inaccuracy due to inadequate computerized systems, lack of designated storage areas, and inappropriate packaging specifications. Based on the results, this study proposed a lean framework that strategically integrates Standardised Work, E-Kanban system, and ABC analysis to eliminate the identified waste. The implementation has resulted in a 45.9% reduction in operational time, improving from 3,339 minutes before intervention to 1,806 minutes after the lean implementation, achieving under 2 days of customer delivery expectations. This study theoretically contributes to the lean integration framework specific to food and beverage depots by providing evidence-based methodology for managers to improve operational efficiency and order fulfilment performance.

Keywords: Efficiency, Lean warehousing, Order fulfilment, Rotated component matrix, Warehouse operations, Kanban

1. Introduction

In 2023, the warehousing market in Malaysia was valued at USD 500 million and is projected to grow to USD 700 million by 2028, indicating that the industry remains stable and capable of supporting increased order fulfilment capacity driven by the rising demand for distribution facilities, particularly in the food and beverage segment [1]. This situation serves as a benchmark for the growing recognition of warehouses as crucial hubs for maintaining a competitive market position [2]. These hubs are vital as operational process nodes where inventory is received, stored, processed, and made available to ensure quick order fulfilment. However, the rapid evolution of the digital world has been a significant challenge in meeting customers' demand for shorter delivery times [3]. As a result, warehouse efficiency has become critical in meeting customer requirement from the point of receipt to the point of delivery and to enhance business productivity [4].

Today, the demand has shifted customers' expectations in the food and beverage industry, ultimately prompting organizations to seek strategies to improve their order fulfilment [5]. Consequently, the shift towards order fulfilment efficiency, such as same-day or next-day delivery, has made warehouse operations more time-sensitive [6]. It has become a global standard timeframe for customers to wait from placing an order until goods are delivered, and they may be willing to sacrifice a day or two of lead time [7]. Although this is critical, delays in delivery are common in order fulfilment. Order fulfilment problems are usually associated with outbound warehouse operations, especially during the picking, packing and sorting processes [8]. Research by [9] and [10] found that receiving and put-away processes are the most critical activities in warehouse operations and require improvement to avoid cascading effects. Their study emphasizes the importance of inbound operations, as the existing inefficiency can disrupt the entire workflow.

Existing literature demonstrates that lean warehousing as innovative solution to optimised operational efficiency via systematic identification and elimination of waste, ultimately improving order fulfilment performance, particularly in food industries [11], [12]. Previous studies have developed various lean frameworks for different purposes, ranging from the application of lean tools, principle validation, and performance measurement [13]. However, the development of existing frameworks reveals significant gaps in how researchers structured and developed lean tools within the processes. Contemporary studies show inconsistent consideration of lean tools integration, particularly in the flow of materials and information in warehouse operations.

Despite lean warehousing's successful implementation across various sectors, its applicability in the food and beverage sector remains underdeveloped, indicates sector-specific knowledge gap and underscoring the need for further research on lean warehousing in this sector [14]. Furthermore, there is an empirical gap in previous studies that have not comprehensively examined the interconnection between warehouse operational efficiencies and their impact on key performance indicators, particularly order fulfilment performance. Therefore, it is crucial to address these gaps by developing a structured lean warehousing framework that integrates operational inefficiencies and specific lean tools to enhance order fulfilment performance.

Therefore, this preliminary study was conducted to investigate bottlenecks within the ASD food and beverage depots over a 12-month period, from September 2024 to August 2025. The timeframe ensures that the data collected is sufficient and accurate for subsequent analysis and a reliable assessment of inbound and outbound operations. These findings contribute to bridging critical knowledge and empirical gaps in lean warehousing applications, particularly in the Malaysian context. This study discusses the following questions: What are the factors affecting warehouse operations and order fulfilment in the F&B depots? Which operational factors most strongly affect order fulfilment in F&B depots and how? How can lean warehousing frameworks optimise warehouse operations to enhance order fulfilment in the F&B depots?

1.1 Literature review

1.1.1 Warehouse operations

A warehouse or depot is a component of storage facilities designed to keep, hold, handle and distribute goods, raw materials or items for a certain period [15], [16] and meet anticipated demand while preventing shortages caused by unexpected orders [17]. Within supply chain systems, these facilities act as a buffer to control supply and demand variations to manage fluctuations in the market [18], [19]. A well-managed warehouse may efficiently satisfy customer requests by fulfilling orders quickly and accurately [20], yet it has evolved into a complex place with many different tasks and operations (4). Consequently, the tasks of effectively and efficiently administering complex warehouses have become more challenging. The most challenging task faced by warehouses is managing the ongoing activities of their operations [21]. This is because operations are closely related to the efficiency of supply chain warehouses, whereas effective operations make a system work better [22]. The most common operations throughout most storage facilities are receiving, put-away or storing, order picking and shipping [3], [4]. Additionally, depending on the type of warehouse, other regular operations may include inspection, staging, zoning, batching, routing, sorting, packaging and consolidating [21], [23]. Collectively, these operational activities determine the success or failure of the overall process flow within a warehouse. Effective coordination of these processes is therefore essential to ensure smooth material movement and operational continuity. Ultimately, as orders are fulfilled and goods are packed, they are made ready for delivery to the customer [24], thereby supporting timely and accurate order fulfilment across the supply chain network.

1.1.2 Order fulfilment

Warehouse operations according to [20] are divided into two categories: (1) inbound operations involve the actions of receiving, put-away, and storing goods, and (2) outbound operations involve order picking, packing, and sorting (activities related to customer, destination, and transporter) that directly concern customer order fulfilment. Within this operational structure, efficient warehouse operations heavily rely on maintaining optimal inventory levels. Therefore, every warehouse consistently strives to maintain an optimal inventory level in order to fulfil its needs while preventing overstocking or stock shortages [24]. In particular, stock shortages may occur due to delays in order placement and fulfilment or incorrect information on product availability [25]. To achieve operational efficiency, warehouses are required to deliver stock with minimal response time, ensuring timely order fulfilment [26].

From an operational perspective, efficient order fulfilment requires effective coordination between inventory management, picking and packing techniques, and shipping activities. In today's competitive marketplace, prioritising fast and accurate order fulfilment has become essential. Consequently, the faster the processes of receiving, processing and delivering are, the quicker the order reaches the customer. Fundamentally, fulfilling orders begins with a customer placing an order and concludes with the delivery of the correct product, in the appropriate amount, at the designated location, within the specified timeframe [20]. Similarly, [27] described order fulfilment as the process of transforming customer requirements into a delivered order that includes receiving and listing the order, as well as physically picking and shipping the goods. Rushton et al., [27] further emphasised that its purpose is to ensure that customer order requirements are delivered in the shortest possible time and with maximum accuracy. However, achieving a balance between delivery efficiency, product availability and customer satisfaction remains a key operational challenge [25]. Therefore, ensuring a perfect order for customers depends greatly on effective inventory management, which is closely linked to inbound operational performance. Figure 1 presents an overview of warehouse operations and order fulfilment.

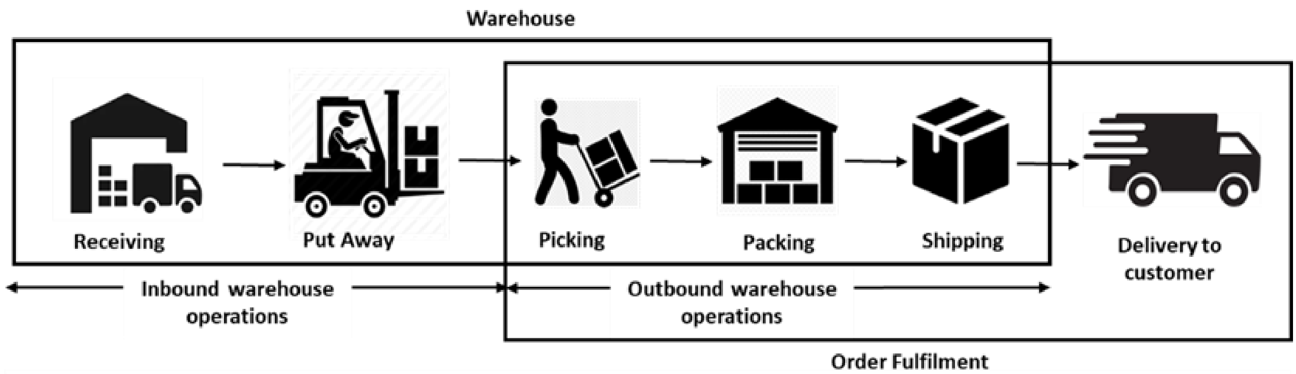

Figure 1. Overview of warehouse operations and order fulfilment [8]

1.1.3 Lean warehousing concept

Existing literature on lean warehousing implementation has proven the achievement of waste elimination in warehouses [13], but examination reveals substantial gaps in how researchers structured and developed lean frameworks within warehouse operations. There is an inconsistency in the implementation of lean tools to address the specific context of the warehouse under study, with a major focus on material flow, information flow and inventory management [28]. In many cases, several researchers have addressed inefficiencies with specific lean tools and their effects in warehouse settings individually. This indicates significant fragmentation in their application of lean tools, with a lack of standardised frameworks and consistent performance measurement addressing multiple operational inefficiencies.

An example of information flow, [16] studied implemented Standardised Work protocols to address the inefficiency of non-existent information flow in SME distribution operations, which caused delays in communication and administrative times. Addressing the same information waste problem, [29] employed a technology approach using Kardex digital systems to improve inventory location and product availability information. Conversely, [26] implemented E-Kanban to optimize communication among training staff, thereby reducing staff response time by 78.94%. While in material flow setting, they also implemented Standardised Work to address poor packing procedures, and their study achieved an increase in On-Time In Full (OTIF) delivery indicators from 67% to 77%. Similarly, [30] applied the same tool to address the same problem by standardising packing and stowage protocols in distribution centres, and the result shows a 16.9% increase in fill rate.

In inventory management, prior studies have used lean tools such as 5S to address warehouse disorganization. For example, [11] studied the implementation of the tool to improve workplace organization through the systematic 5 stages of product organization, achieving an increase in inventory turnover from 4 to 12 times per year. Conversely, there is a popular technique used to organize inventory based on demand frequency classification to improve service level performance, which is ABC analysis. Study done in [31] integrated ABC analysis with facility design, showing an improvement in on-time service performance, which resulted in a 30.55% improvement. Similarly, [29] implemented ABC classification analysis based on Pareto principles to improve location allocation data, and they achieved a 33.12% reduction in order preparation time, leading to a 69.24% increase in OTIF. However, their studies show different applications of lean tools across warehouse operations: 5S reduces inefficiencies in inbound operations, while ABC analysis reduces inefficiencies in outbound operations, and both tools serve fundamentally different purposes.

Despite these achievements, the majority of these studies applied lean tools independently and do not provide structured frameworks that integrate Standardise work, Kanban, and ABC analysis for warehouse improvement, particularly in the inbound food and beverage depot, and leaving this topic remain underdeveloped.

1.1.4 Kanban

Major issues in inventory management are typically related to discrepancies between physical units and those documented in the company's system [32], the more items are handled, the greater the risk. Thus, Kanban is an effective control system that provides a visible tool by carding system for managing inventory. In food industry, [11] organised Kanban cards to identify the incoming and outgoing quantity of goods, allowing accurate information for operators or material handlers, leading to increase inventory accuracy. Conversely, Perez-Canchanya et al. [12] utilised Kanban and Standardise work to eliminate waste focussing on examining how Kanban improve information visibility to control inventory related with accumulation of tasks and non-conforming items. Briones-Chávez et al. [26] implemented E-Kanban in response to the advancement of technology. Their primary objective is to reduce communication time by assisting the company in the definition and classification of SKUs based on the type of task priority and the location of the activity. Subsequently, the technology creates visibility of demand information to the supplier, shortening the logistics lead-time.

1.1.5 ABC classification

The ABC classification tool facilitates systematic item classification while ensuring effective inventory management and control [31]. This tool classifies inventory items into 3 classifications: A, B, or C under Pareto principle analysis based on their consumption value per year [30]. By identifying high-value, fast-moving items (A), moderate-value items (B), and lower-value, slow-moving items (C), warehouse managers can make informed decisions about optimal storage locations. When properly implemented, this classification system ensures that frequently accessed items are positioned for maximum accessibility, while items with lower turnover rates occupy less premium storage locations. For instance, classification determines that perishable food products with higher consumption rates or shorter shelf lives can be in easily accessible slots to speed up picking, while reducing spoilage [33]. It helps to improve storage organisation, leading to a reduction of transportation waste and distance travelled in warehouse operations. Consequently, this optimisation directly contributes to reduced picking times, decreased operator movements, and ultimately enhanced order fulfilment performance throughout the entire warehouse operation.

1.1.6 Standardise work

Standardise work refer as the process of establishing a work method that follows a set of predetermined standards [34]. It is widely used to define specific job procedures and to ensure the efficiency of any operation that requires completion on time, according to the required standard [35]. Using the standardised work tool makes it easier to organise the process by ensuring that each step is consistent, thereby facilitating the detection of workflow problems. Studies done by [36] and [37] state that standardising work in warehouse operations can enhance responsiveness and efficiency in order picking activities. They further indicate that combining standardisation with co-creation can be an effective way to create robust work environments. Similarly, a study by [38] emphasised the necessity of implementing a Standard Operating Procedure (SOP) for the unloading and sorting process, incorporating methods to enhance inspections and quality control of procured items. The implementation helps reduce wait times, errors, and unnecessary travel. Thus, it serves as a systematic approach to documenting and identifying efficient processes to complete a task, with the goal of eliminating waste.

1.2 Contribution

1.2.1 Framework basis

Table 1 summarises the application of the lean warehousing framework relative to existing research in warehousing environments, revealing how this study extends current knowledge. Although these studies demonstrate significant improvements in the targeted performance, most of them were implemented according to the operational priorities such as standard operating procedure, communication and inventory organisation. The targeted performance indicator also varies across literature including OTIF, inventory turnover, production efficiency and order fulfilment enhancement. However, limited research has developed an integrated lean warehousing framework to address specific warehouse operational inefficiencies simultaneously, especially within the food and beverage depot environment. Furthermore, the comparison reveals that existing research addresses 2 or 3 core warehouse functions. Material flow improvement is mostly addressed via standardised work, but few have applied SMED or VSM. While information flow is often achieved using Kanban or a digital system, inventory management improvement depends on the operational inefficiencies requirement context, either to apply 5S or ABC analysis.

The 5S tool focuses primarily on inventory and workstation organisation to improve efficiency and eliminate waste via removal, assignment, cleaning and disposal, standardization, and discipline in a warehousing environment[11], [14]. However, the tool does not consider a quantitative method to classify inventory by demand frequency or time-sensitive items, which is critical for a warehouse. Conversely, ABC analysis offers items prioritization, a method to easily identify fast-moving items and allocate storage locations close to the pick face to reduce travel distance, slow-moving items occupy storage with minimum accessibility [28]. For instance, classification determines that products with higher consumption rates or shorter shelf lives are in easily accessible slots to speed up picking process, while reducing spoilage [33]. Therefore, ABC analysis is more appropriate for inventory management optimization by providing product prioritisation, while 5S is primarily used for inventory or workplace organization.

Table 1. Comparison matrix of lean warehousing intervention

Authors	Industry	Lean Warehousing Intervention			Targeted Performance
		Material Flow	Information Flow	Inventory Management	
Espino-Sanchez et al. (2022)	Food Suppliers	Standardise work	Kanban	5S	Inventory turnover
Ambrosio-Flores et al. (2022)	SME Distribution	-	Standardise work, BPM	5S, ABC analysis	Order fulfilment
Vasquez-Quispe et al., (2023)	SME commercial	Standardise work	Kardex	5S, ABC analysis	OTIF
Perez-Canchanya et al., (2023)	Food company	SMED, Standardise work	Kanban	-	Order fulfilment
Briones-Chávez et al., (2025)	Logistics SME	Standardise work	Kanban	5S	OTIF
Proposal	Food and beverage depots	Standardise work	Kanban	ABC analysis	Order fulfilment

Therefore, this study differs from previous literature, emphasising 3 key gaps: lack of a unified framework by combining the 3 lean tools, such as standardised work, Kanban, and ABC, limited focus on warehouse operational bottlenecks affecting order fulfilment, and application within food and beverage depot operations, where inventory management becomes challenging in operational situations**.** Most prior studies examine and address outbound operations, but examining inbound operations remain underexplored. Additionally, there is a lack of empirical evidence from previous studies, where most of the literature primarily conducted in Western regions, but only one study implemented lean warehousing in the Malaysian context. The gaps identified are the reason for this framework's primary contribution.

1.2.2 Proposed lean warehousing framework

This study proposes a lean warehousing framework adapted from [26] framework with some modifications that operates through a systematic five-stage process designed to improve warehouse operational efficiency from suboptimal performance to better order fulfilment performance. The proposed framework differs from their study as the order fulfilment lead time was quantified based on the best practice standard of delivery, where it should not exceed more than 2 days of delivery, rather than On Time and In Full (OTIF) performance. The selection of order fulfilment as the proposed framework performance is suitable for this study, which is concerned with the warehouse operational process from order receipt to final delivery, while OTIF is limited to measuring delivery time and accuracy outcomes.

Figure 2 presents a five-stage lean warehousing framework for the depots. In stage 1, the order fulfilment lead time is considered high when the number of delivery days exceeds the 2-day threshold, showing a significant inefficiency in the warehouse that requires elimination and systematic improvement through lean interventions. Stage 2 of waste identification uses various analytical approaches, including survey-based data collection, principal component factor analysis (PCA), descriptive statistics, and correlation analysis. This stage employs SPSS software for statistical validation, marking a significant methodological contribution by integrating quantitative analysis as a methodology of waste identification processes. In stage 3 of intervention, the elimination of waste using selective lean tools, targeted inefficiencies identified at stage 2 in sequencing: standardise work, E-Kanban, and ABC analysis. These tools are expected to eliminate inefficiencies identified in the inbound and outbound operations that increase processing time. Evaluation analysis in stage 4 emphasizes quantifiable outcomes, particularly cycle times for processing inventory from receipt to the storage area to maintain availability, and for order preparation from picking to delivery to fulfil customers' requirements. Output analysis in stage 5 determines the level of order fulfilment performance. Low order fulfilment lead time is achieved when the time to fulfil customer orders is below 2 days (<2 days delivery), demonstrating successful waste elimination, operational transformation, and enhanced order fulfilment performance.

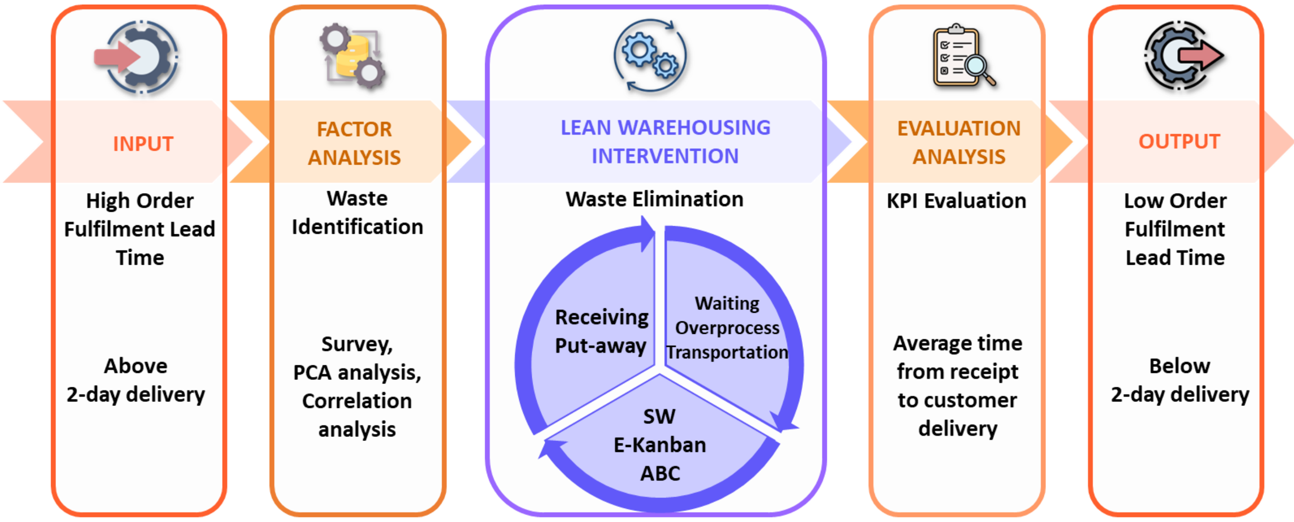

Figure 2. Proposed lean warehousing framework

2.0 Method

This study used an explanatory sequential mixed-methods design conducted over a 12-month period from September 2024 to August 2025. The study was completed to prepare a manuscript for publication in 2026, focusing on an empirical assessment and the development and validation of a lean warehousing framework through time studies of the warehousing process. The study involved collecting quantitative data, analysing the results, and then gathering qualitative data to provide more detailed explanations. This cross-sectional survey method is designed to provide quantitative descriptions of the phenomenon, allowing for simultaneous comparisons of variables and cost-effective reporting [39], [40]. Meanwhile, the qualitative approach was used for data collection in the second phase, building on the quantitative results to enhance data triangulation, supporting the validity and reliability of the findings [38].

In the initial phase, to assess the current condition of the warehouses under study, a quantitative approach was employed between September 2024 and April 2025, with questionnaires as the primary data collection tool [40]. The study was divided into 4 stages to investigate the warehouse practices : instrument development, pilot testing, large- scale distribution, and statistical analysis. In stage 1, the questionnaires consisted of 25 structured questions specifically designed to identify potential operational inefficiencies. The items were adapted from established questionnaire protocols developed by [23] and supplemented with items from [41] research framework. All items utilized a five- point Likert scale (1- Strongly disagree, 2- Disagree, 3- Moderate, 4- Agree, 5- Strongly agree), due to its reliability and ease of analysis using statistical techniques [42]. The questionnaire was reviewed by experts, academicians, and practitioners to ensure reliability and clarity [43]. After amendments, in stage 2, it was piloted to assess reliability and validity [44]. A pilot test with 25 respondents from a food and beverage warehouse showed a Cronbach' s alpha of 0. 869, exceeding the minimum level of 0.7, indicating good internal consistency [45]. In stage 3, following successful pilot validation, respondents were selected among supervisors and operational staff, targeting personnel directly involved in warehouse operations: receiving, put- away, storage, picking, and shipping, to capture logistics operational perspectives. The questionnaires were distributed to respondents across 15 regional food and beverage depots throughout Malaysian ASD, with a total number of 300 questionnaires. After removal of potential incomplete or unreliable responses from the respondent, the final number is considered large, ranging between 100 and 200 responses [47]. This means that a sample size adequate for statistical analysis of factor loading analysis exists. The determination of the distribution number for the respondent is accounted to ensure broader coverage of the target population and to assess whether the sample size is sufficient after considering incomplete responses, straight-line responses, and non-response [43].

At the final stage, once collected, the quantitative data underwent rigorous statistical analysis using SPSS software. The analysis began with Kaiser- Meyer- Olkin (KMO) and Bartlett' s tests to determine suitability for PCA, followed by systematic factor extraction procedures. After that, Principal Component Factor Analysis (PCA) with varimax rotation was applied to reduce the measurement items and group them into several components for key operational factors identification. The resulting rotated component matrix was carefully examined to identify which metrics group together into meaningful factors. For further analysis, correlation analysis was employed to examine the relationship between warehouse operations and order fulfilment. The emerging relationship exists among the elements, will be considered for improving the depot within the framework of lean warehousing.

In the second phase, observations were carried out between July and September 2025 to gather data at a selected depot using participant observation methodology. This approach requires the observer to collect data by engaging in the daily routines of the warehouse under study through planned monitoring, recording, and analysis of events. Time studies were conducted to measure the duration of normal processes, identify activities that add value and those that do not, and determine the time taken for each. The first time point study will be performed to examine the flow of warehouse operations before optimisation. The second time point will be after waste has been eliminated from the process flow, and performance will be measured to assess any differences between the two points. In the final stage, a lean framework proposal is introduced as a strategy to improve order fulfilment in the depot.

3.0 Results and discussion

This study was conducted to answer the research questions, using data adapted from previous literature. This data was processed to develop a set of questionnaires. The questionnaires were then distributed to employees in 15 food and beverage depots across Malaysia. The depots were selected because they represent organisations that provide food and beverage distribution services and perform the same warehouse operations, including receiving, put-away, order picking, and dispatching, reflecting typical warehouse operational conditions. These depots handle a wide range of products with the capacity to hold over 200 product variants, including perishable and non-perishable goods, and serve as key distribution centres for storage and direct delivery to customers and food service establishments.

3.1 Response rate

In phase 1 of this study, a total of 300 questionnaires were distributed to 15 depots online, and 278 respondents from 13 depots (86.7%) completed and returned the questionnaires, which is a good result for a study conducted. Response screening was carried out, and the results showed that 71 responses were removed due to straight-line answers that were not suitable for inclusion in this study. After the final review, only 207 responses were selected, accounting for 74.5% of the responses. The sample size of n=207 exceeds the minimum response rate of 60% and is considered adequate for a study; a response rate above 60% is viewed as competent, and a rate between 60% and 80% is considered sufficient [46]. Subsequently, all data collected from the targeted respondents were analysed using Principal Component Factor Analysis (PCA) with varimax rotation to reduce the factors (items) into a manageable number before further analysis, in order to identify warehouse operation inefficiencies and their impact on order fulfilment performance. The survey data were then transformed into understandable information.

3.2 Analysis on data reduction procedure

The data consists of 25 questions or items designed to measure two constructs: warehouse operations and order fulfilment. Table 2 shows that Bartlett's Test of Sphericity was significant, with a Chi-square value of 3134.704 and a p-value less than 0.001. The measure of sampling adequacy, the Kaiser-Meyer-Olkin (KMO) test, is 0.887, which is above the acceptable threshold of 0.6. According to Ref. [47], a KMO value close to 1.0 and a significant Bartlett's Test indicate that the data is suitable for factor analysis. The KMO value of 0.887 is excellent, exceeding the recommended minimum of 0.6 [48]. These two measures suggest the data is appropriate for reduction. Principal Component Factor Analysis (PCA) with varimax rotation was applied to the 25-item dataset and the analysis identified several underlying component factor structure, while achieving data reduction. Based on Kaiser's criteria in [47] and [48], the number of components retained is determined by factors with eigenvalues greater than 1.0. This threshold indicates the minimum variance a component must explain to be considered significant, equivalent to the variance of a single standard variable. Components with eigenvalues less than 1.0, which explain less variance than individual variables, are deemed insufficient and are excluded from interpretation.

Table 2. KMO and Bartlett's test for warehouse operations and order fulfilment

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.887
Bartlett's Test of Sphericity	Approx. Chi-Square	3134.704
	Df	300
	Sig.	<.001

The analysis continues with the use of Principal Component Factor Analysis to extract the underlying latent components based on total eigenvalues and variance. The PCA output shown in Table 3 indicates that a total of six distinct components were extracted, each with eigenvalues greater than 1.0.

Table 3. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.322	37.287	37.287	9.322	37.287	37.287
2	2.157	8.628	45.915	2.157	8.628	45.915
3	1.691	6.765	52.679	1.691	6.765	52.679
4	1.507	6.028	58.707	1.507	6.028	58.707
5	1.425	5.701	64.408	1.425	5.701	64.408
6	1.059	4.236	68.644	1.059	4.236	68.644

The process continues to identify the items associated with each of the six components. According to [49], an item that loads greater than 0.6 on one component (e.g., component 1) and less than 0.35 on the other components should be assigned to that component. If an item has a loading higher than 0.6 on one component and also a loading above 0.35 on other components, it is considered to have positive cross-loading and should be removed from further analysis. Similarly, items with factor loadings below 0.6 across all components should also be excluded from the analysis. The selected items, which are above the criteria, are grouped under the respective component. Table 4 presents the factor loadings for all 25 items across the six identified components, namely components 1, 2, 3, 4, 5, and 6. The factor loadings in bold indicate which component their respective items fall into, measuring how strongly each of the items relates to the underlying operational issues. Quantitative measurement of the factor loadings 'rule of thumb' suggests that the higher the value, the closer it is associated with the warehouse operational issue. Items and components identified were grouped into a single mean value that represented their respective components.

Table 4. Items factor loading value under distinct component

Ser	Items	Component					
		1	2	3	4	5	6
1	Suppliers followed the delivery time schedule that was specified		.382			.308	
2	Incoming shipments are inspected for quality and specification in short time frame.						**.782**
3	Supplier delivered goods with the most suitable packaging to expedite put-away.					**.830**	
4	There is enough space to store incoming goods without moving existing goods						**.702**
5	Technology is available for documenting goods.		**.619**				.370
6	The warehouse layout facilitates placing of received items.	.303	**.717**				
7	Information displayed on deliveries is correct and visible.		**.791**				
8	There is available equipment for storing item when is needed		**.799**				
9	There is a designated area for storing high-demand items.					**.737**	
10	There is a computerized system to allocate item locations.					**.810**	
11	Technology is used in picking operation.		.475	.596			
12	Staff picking route and movement are efficient within the warehouse.			**.779**			
13	Staff are adequately trained on proper picking techniques.			**.876**			
14	Staff sorted the items ordered while picking.	.305		**.804**			
15	The staff accurately picked the exact quantity of the item that is required.		.350		.595		
16	Loading in the carrier takes less time for dispatch.				.643		
17	Dispatch staff check that the picked item quantities are correct.	.412			**.642**		
18	There is a sufficient supply of packing material.	.317			**.765**		
19	The packing material is located close to the packaging area				**.797**		
20	There is sufficient space loading bay to stage order.			.339	.637		.349
21	Orders are being delivered on time to customers.	**.811**		.315			
22	Customers received correct number of items.	**.723**	.363				
23	Orders are being delivered without any damage.	**.696**					
24	Product are delivered without rejects.	**.756**		.340			
25	Orders are being delivered accurately to customers' locations.	.500					

Following the suggestion by [49], Table 5 presents the reliable items under distinct components. The factor analysis procedure resulted in the retention of 14 of 25 items within their respective components. After the reduction, the remaining 14 items with higher factor loadings indicate a stronger relationship with the operational factors affecting warehouse efficiency and order fulfilment performance. These items were then grouped into 6 distinct components, which were renamed to reflect meaningful operational constructs within warehouse management: order fulfilment (C1), storage (C2), order picking (C3), shipping (C4), put-away (C5) and receiving (C6). The SPSS results analysis revealed that order fulfilment is the mean of items 10, 13 and 14, storage is the mean of items 4 and 5, order picking is the mean of items 8 and 9, shipping is the mean of items 11 and 12, put-away is the mean of items 2, 6 and 7 and receiving is the mean of items 1 and 3. Thus, the grouping of items has reduced the data to 6 distinct categories instead of dealing with 25 items. The resulting 6 components identified provide a foundation for subsequent analysis examining the relationships between warehouse operations and order fulfilment items. This dimensional reduction approach enables more focused investigation of how specific operational items within each component affect order fulfilment, thereby facilitating targeted improvement strategies for warehouse optimization.

Table 5. Reliable items under the respective components

Ser	Items	Component					
		1	2	3	4	5	6
1	Incoming shipments are inspected for quality and specification in short time frame.						**.782**
2	Supplier delivered goods with the most suitable packaging to expedite put-away.					**.830**	
3	There is enough space to store incoming goods without moving existing goods.						**.702**
4	Information displayed on deliveries is correct and visible.		**.791**				
5	There is available equipment for storing item when is needed		**.799**				
6	There is a designated area for storing high-demand items.					**.737**	
7	There is a computerized system to allocate item locations.					**.810**	
8	Staff picking route and movement are efficient within the warehouse.			**.779**			
9	Staff are adequately trained on proper picking techniques.			**.876**			
10	Loading in the carrier takes less time for dispatch.				**.643**		
11	Dispatch staff check that the picked item quantities are correct.				**.642**		
12	The packing material is located close to the packaging area				**.797**		
13	Orders are being delivered on time to customer.	**.811**					
14	Orders are being delivered without any damage.	**.696**					

3.3 Descriptive statistics

The collected data on items was analyzed under respective components or variables using descriptive statistics to further observe the current state of the depots in the study, as shown in Figure 3. The descriptive statistics were presented by measuring the frequency of items captured within each variable. The analysis examines respondents' perceptions of warehouse operation efficiency across five operational variables in their depots. The survey utilized a 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" to assess the perceived level of warehouse performance based on respondent feedback. The bar chart reveals three distinct performance levels in the depots: high-performing operations (storage, shipping, picking) with 75 to 80% satisfaction, low-performing operations (receiving and put-away) with 40 to 51% satisfaction, and moderate-performing operations (order fulfilment) at 72% satisfaction. It is observed that each category shows differences in performance levels, as reflected in the analysis results. The high satisfaction rates in storage, picking, and shipping demonstrate the depots' capability to achieve operational excellence. However, the low performance in receiving operations (40.6% satisfaction) highlights a critical bottleneck that may limit overall system performance despite efficiency in outbound operations.

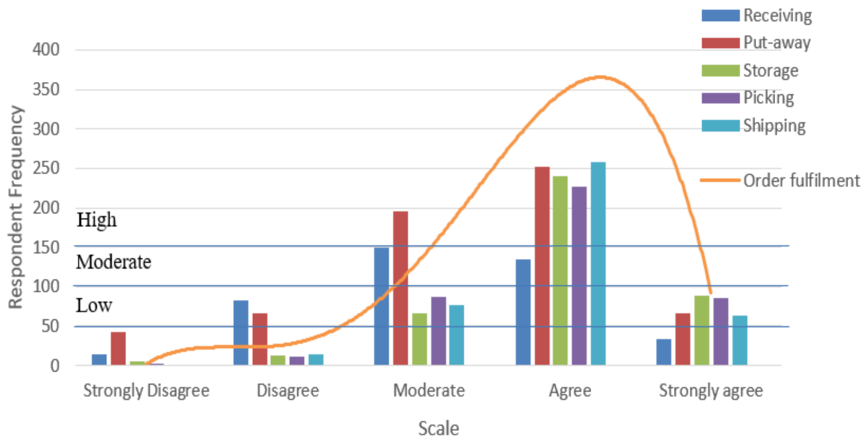

Figure 3. Descriptive statistics of warehouse operations and order fulfilment performance

The result of the descriptive analysis is demonstrated in Figure 4, where the most significant factor affecting order fulfilment in the depots was inbound operations, due to low efficiency in receiving and put-away operations. However, outbound operations are more efficient than inbound operations, with minimal identification of non-value-added activities. The major problems contributing to the low efficiency in receiving and put-away are identified as inspection time, space availability, information accuracy, designated areas, and packaging specifications. After an initial investigation, it was discovered that these inefficiencies have affected order fulfilment, leading to delayed deliveries and damaged items. Figure 4 illustrates the common causes of delays in both inbound and outbound operations.

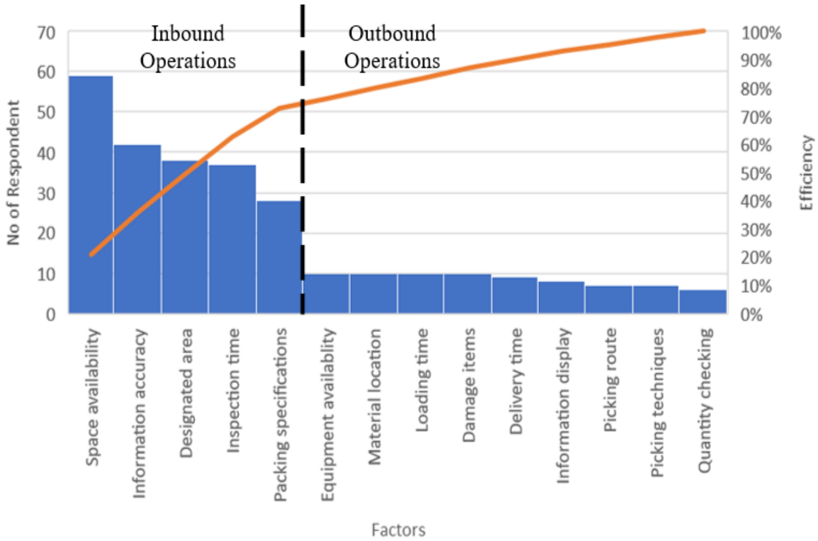

Figure 4. Bar chart of descriptive statistics of warehouse operations issues

3.4 Correlation analysis

Using SPSS, the relationship between warehouse operations and order fulfilment performance was analyzed by examining a sample of n=207 to assess both the linear relationship using Pearson's correlation coefficient with statistical significance at $p < .05$. The use of Pearson correlation coefficient is considered appropriate to this study as it examine the direction, strength and statistical significance of the bivariate relationship between variables measured at interval levels [43]. According to [43], Likert scales are used to measure opinions, and the aggregated responses are generally treated as if they were interval scales. Furthermore, the sample size is considered large, allowing Likert scale responses analysed using parametric statistical techniques. Therefore, this study applied Pearson’s correlation analysis to examine the strength and significance of relationships between warehouse operational factors and order fulfilment performance by statistically analyzing how warehouse operations factors correspond with order fulfilment outcomes. The key factors identified early in the descriptive analysis were quality inspection time, space limitations, packaging specifications, lack of designated locations, information inaccuracies, and their impact on delivery performance and on goods damage. Table 6 presents the results of the correlation analysis. The analysis revealed critical operational factors affecting delivery performance and item damage. Several factors emerged as statistically significant in relation to operational outcomes.

Table 6. Correlation analysis results

Operational Factors	Correlations	Order fulfilment	
		Delay Delivery	Damage
Information inaccuracy	Pearson Correlation	.288**	.259**
	Sig. (2-tailed)	.001	.001
Lack of a designated area	Pearson Correlation	.196**	.293**
	Sig. (2-tailed)	.005	.001
Lengthy quality inspection time	Pearson Correlation	.045	.177*
	Sig. (2-tailed)	.517	.011
Unsuitable packaging specification	Pearson Correlation	.138*	.148*
	Sig. (2-tailed)	.047	.033
Limited space for incoming goods	Pearson Correlation	-.004	.123
	Sig. (2-tailed)	.957	.076

The correlation analysis identified information inaccuracy caused by deficient computerized systems referring as the strongest factor affecting operational factor on both delayed delivery and damaged items supported by Pearson correlation result ($r=.288^{**}$, $p<.01$). Information is concerned with the details of inventory data relates to stock levels, locations, movements, and criteria. Any discrepancies between record and actual stock may occurs when they are communicating verbally, reentering of data or redundant record keeping, can led to delays updates, or miscommunication [28]. These errors may propagate across the depots, from upstream to downstream of the operational process, affecting delivery performance or product quality. For instance, when staff at each station manually fill out the form using paper-based records, they spend additional time duplicating the same data for the item, which disrupts the warehouse's operational efficiency and contributes to delayed order fulfilment. This finding emphasizes the importance of communication regarding the information technology infrastructure in warehouse operations, where system reliability directly impacts efficiency in processing materials and information. The SPSS analysis also presents a positive relationship between the lack of designation of SKU allocation and delayed delivery, proving that the issue of storage allocation can cause operational inefficiency related to an increase in travel distance, time, and unnecessary movement [28]. Additionally, the absence of designated storage areas shows the strongest connection to item damage. This emphasizes the importance of systematic storage organization in damage prevention strategies. Information on where the items are allocated is important to avoid randomly placing the SKU. Consequently, randomly placing SKUs may cause item deterioration due to a lack of visibility into the item's location or frequent SKU moves during searches or item retrieval, leading to rework on damaged items.

However, unsuitable packaging specifications showed a weak but statistically significant positive correlation with delayed delivery. This suggests that poor packaging standards cause operational disruptions, including storage problems, repacking delays, and handling inefficiencies. These findings underscore the importance of supplier packaging standards and quality control in ensuring timely delivery while maintaining swift order fulfilment. Conversely, the correlation between limited space for receiving goods and both delayed delivery and damaged items is weak and statistically insignificant. This indicates that limited space has a lesser effect and does not directly influence order fulfilment. Similarly, quality inspection time has weak positive relationships with operational outcomes. The non-significant link with delayed delivery suggests that inspection processes operate independently of delivery schedules, reflecting an efficient workflow that prevents quality control from delaying deliveries. However, the significant positive relationship with damage indicates that longer inspection times increase the risk of damage, likely due to excessive handling and manipulation during extended examinations. Figure 4 illustrates a framework on the operational inefficiency relationship with order fulfilment.

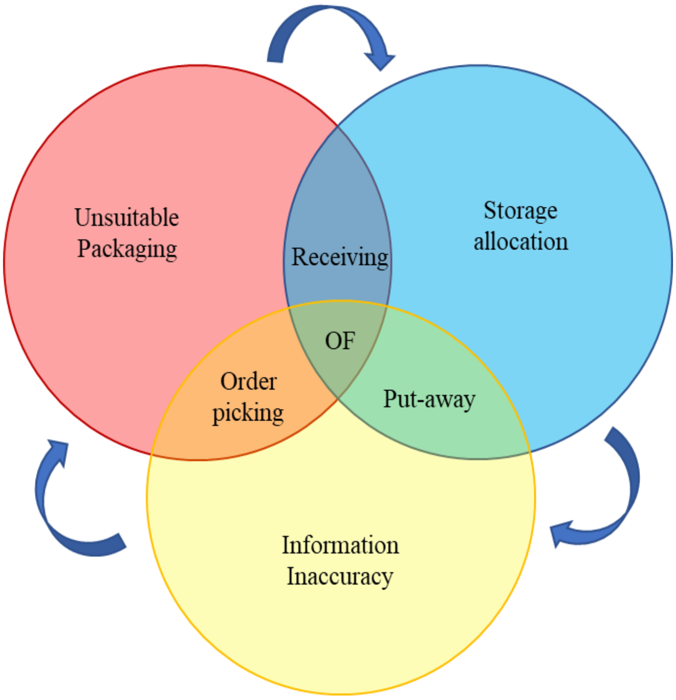

Figure 4. Framework on the operational inefficiency relationship with order fulfilment

(Source: created by authors)

3.5 Validation

Table 8 presents data collection conducted through a detailed time-observation study of key warehouse processes at a selected food and beverage depot. The time study measured the duration (in minutes) four times to calculate the average time for an order. By observing the flow process, we identified the time consumed for each activity in the depot operation. The durations of each activity were summed, and the four observation times were used to calculate the average. Based on the collected data, the analysis reveals that receiving, put-away, and picking operations are the most time-consuming stages within the warehouse process cycle. These three main activities account for the highest proportion of time in preparing orders for customers. Addressing waste identified in these activities can improve information accuracy, increase space, standardize packaging requirements, and ultimately reduce unnecessary delays.

Table 8. Time study for operational activities

Time observation table			Observer:		Mohd Khidir Osman		Average (Min)
Process	Activity Name	Total Activities	Study Number (Minutes)				
			1	2	3	4	
1	Receiving	29	144	135	143	150	143
2	Checking	8	4	5	5	6	5
3	Put-away	20	104	117	108	111	110
4	Picking	13	131	135	129	128	131
5	Packaging	9	43	52	50	51	49
6	Consolidate	3	20	23	22	19	21
Total Lead Time							**459**

Table 9 presents the proposed lean tool interventions designed to eliminate waste in warehouse operations. Using these tools is expected to improve the company's depot activities by greatly reducing wastes related to waiting, overprocessing, and transportation. This focused approach aligns with lean principles to make operations more efficient and overall better.

Table 9. Propose a lean tools intervention for eliminating waste in warehouse operations activities

Activity	Waste	Observation	Intervention Proposal
Receiving	Waiting	It was observed that incoming items were unloaded, but workers had to wait for the items to be fully stacked on pallets due to non-standardized package dimensions, weights, or configurations. This waiting period appeared to slow down the unloading process and reduce overall efficiency.	The homologation process improves coordination between the supplier and depots, enabling faster receiving and put-away processes by aligning packaging specifications to ensure incoming stock is packed and stacked according to the customer's requirements. Establishing standardize packaging specifications can be supported through documented procedures, visual guidelines, and clear communication guidelines with suppliers to ensure consistency and efficiency.
Checking	None	It was observed that incoming items were checked to verify their specifications, labelling, and weight during the receiving process.	None
Put-away	Overprocessing	It was observed that repeating some information in different formats, caused by a deficient computerized system, led to data discrepancies. This practice appeared to add no value to the customer and contributed to inefficiencies in information handling.	Reducing the use of forms by implementing E-Kanban cards and boards can enhance workflow efficiency. This strategy provides a visual management tool that offers clearer information on SKU locations and availability, leading to a reduction in data discrepancies and an increase in upstream visibility
Picking	Transportation	It was observed that SKUs were stored in random lanes without designated areas, which appeared to increase the distance travelled and time taken during the picking process.	Reducing picking distances for high-demand items can be achieved by strategically placing them at the pick-face using ABC analysis. This data-driven approach to storage allocation optimizes the warehouse layout and enhances order fulfilment
Packaging	Overprocessing	It was observed that deliveries were frequently broken down into smaller increments through repackaging, which caused additional handling and processing delays. The repackaging of SKUs to meet customer requirements appeared to create unnecessary complexity.	Eliminating the repackaging process can be effectively achieved by implementing standardized work protocols that clearly specify optimal packaging requirements. This includes documenting procedures that address typical issue patterns and labelling requirements to ensure efficient workflow
Consolidate	None	It was observed that the operator consolidated items onto pallets according to customer orders. The items were then distributed based on the specific requests from customers.	None

Table 10 shows the time study table used for quantitative assessment to compare pre-intervention and post-intervention for order preparation times. The first point in time was conducted to examine the flow process of warehouse operations activities before optimisation. The second point in time is where the waste in the process flow has been eliminated, and performance will be measured to see if there is a difference in changes at both points in time. Data were collected and presented in the table for comparison analysis is to provide explanation of the quantitative finding. The table demonstrates significant operational gains following lean warehousing implementation, with total cycle time decreasing from 3,339 minutes to 1,806 minutes, a 45.9% reduction in overall process duration. This notable improvement confirms the effectiveness of targeted lean interventions across multiple warehouse operational stages, as per Briones-Chaves et al. framework, slightly exceeding their result of 43.75%. The cycle time reductions were observed across four critical activities: receiving, put-away, picking, and packaging. These improvements directly relate to the three strategic interventions proposed by the researchers: standardizing item packaging specifications, implementing Kanban visual management systems with cards and boards, and systematic storage classification based on ABC analysis principles. The 45.9% lead time reduction indicates successful elimination of non-value-added activities, such as unsuitable packaging specifications and lack of designated locations, which previously hindered warehouse operations. This efficiency gain directly translates into increased order fulfilment capacity.

Table 10. Time study between current state and future state per order

Ser	Activity	Current (Min)	Ser	Activity	Future (Min)
1	Receiving	143	1	Receiving	129
2	Checking	5	2	Checking	5
3	Put-away	110	3	Put-away	75
4	Picking	131	4	Picking	123
5	Packaging	49	5	Packaging	13
6	Consolidate	21	6	Consolidate	21
	Total Time	**459**		**Total Time**	**354**
7	Supplier Lead Time	2,880	7	Supplier Lead Time	1,440
	Total Lead Time	**3,339**		**Total Lead Time**	**1,806**

4.0 Conclusions

This research focuses on optimising warehouse operations of ASD food and beverage by developing a comprehensive LW framework that systematically identifies and eliminates operational inefficiencies affecting order fulfilment performance. This paper employs a mixed-methods research involving survey on depots efficiency among 207 respondents across 13 regional depots. The collected data from the distributed survey identified several the study uncovers notable performance gaps: while outbound operations (storage, picking, shipping) reach satisfaction rates of 75-80%, inbound processes (receiving, put-away) face critical bottlenecks with only 40-51% satisfaction.

Statistical analysis using PCA reveals that correlation studies identify three primary operational inefficiencies significantly affecting order fulfilment: information inaccuracy caused by inadequate computerized systems ($r=.288$, $p<.001$ for delayed delivery; $r=.259$, $p<.001$ for damage), lack of designated storage areas based on turnover analysis ($r=.196$, $p<.005$ for delayed delivery; $r=.293$, $p<.001$ for damage), and unsuitable packaging specifications from suppliers ($r=.138$, $p<.047$ for delayed delivery; $r=.148$, $p<.033$ for damage). These findings show that inbound operational inefficiencies cascade throughout the entire warehouse system, ultimately compromising order fulfilment despite outbound operational success.

This study proposed a five-stage LW framework that strategically integrates three complementary lean tools: Standardized Work for packaging specification consistency, E-Kanban systems for enhanced information visibility and location management, and ABC analysis for optimal storage allocation based on turnover frequency. Implementation validation shows substantial operational improvements, with total cycle time decreasing from 3,339 to 1,806 minutes, representing a 45.9% efficiency gain. This significant improvement directly translates into a shorter order fulfilment lead time, whereas a complete order cycle of less than 2,880 minutes (<2 days) is considered efficient.

The framework's theoretical contribution lies in the systematic organization of lean tools specifically tailored for food and beverage depot settings, moving beyond variations of lean tool use toward operational processes transformation. Practically, it gives depot managers an evidence-based methodology that balances efficiency gains with existing operational constraints. Future research can assess the applicability of the proposed framework to other service sectors with operational criteria similar to those of the specific-context warehouse with time-sensitive operations, such as agricultural food, frozen food, dairy, e-commerce center and pharmaceuticals. Furthermore, the framework can serve as a reference model that enables replication across various operational contexts, particularly in the service sector such as medical and military, thereby advancing the application of lean warehousing knowledge in the Malaysian environment.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

Mohd Khidir Osman and Prof Effendi Mohamad contribute to the conceptualization of the study and development of the framework. Mohd Khidir Osman and Dr Nurhayati Kamarudin were involved in instrument development, data collection, and data analysis. All authors contribute to writing, reviewing and editing the research final output.

Informed consent

Informed consent for the publication of personal data in this article was obtained from the participants.

Declaration of use of AI in the writing process

The author(s) used Quillbot AI during preparation of this work for grammar checker. The author(s) reviewed and edited the work as necessary and take(s) full responsibility for the final version.

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