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Optimization of Warehouse Operations for Upstream Service Companies in the Oil & Gas Industry: A Case Study

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Abstract: The oil and gas (O&G) sector drives various parts of Malaysia's economy and accounts for 19% of government revenue in 2021. The volatility of oil prices and the COVID-19 pandemic problem in recent years has taught O&G enterprises, especially upstream players, to focus on business needs and employ cost optimization techniques to compete and survive uncertain circumstances. This study seeks to analyze and describe the warehouse operations setup of an onshore supply base service organization that manages and maintains offshore O&G facilities. This study examines space utilization variables from several supply chain perspectives, particularly operations performance. Semi-structured interviews, site observations, and documentation review are used to collect data for the single-case study. The study findings suggest the organization under study has a basic warehouse setup with lean operations staff to complete business functions. In general, the warehouse arrangement for the organization under investigation is comparable to a distribution center, where 70% of warehouse activities comprise, material receiving, handling, and distribution (loading) to several offshore locations. Findings also showed that two factors, namely: *material handling flow and movement*, and *inventory movement* affect warehouse space utilization. The volume of material handled by the warehouse based on business demand, as well as the seasonal trend from offshore activities contribute to the frequency of material loading and impact the material throughput and transit time, which were found to have an impact on space utilization too.

Keywords: *Oil and Gas, Warehouse Optimization, Qualitative, Case Study, Supply Chain, Malaysia*

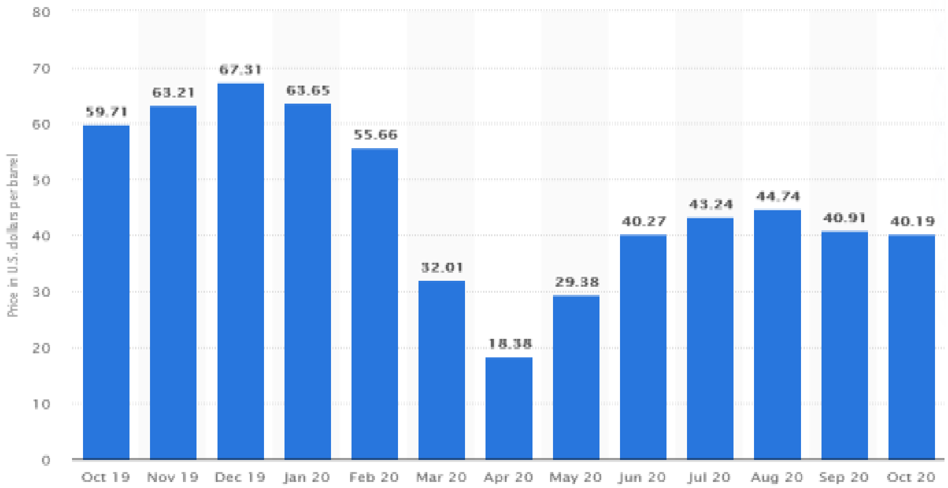
1. Introduction and Background

The oil and gas industry is usually divided into three major sectors: upstream, midstream and downstream. The upstream sector mainly refers to exploration and production activities (E&P) to extract oil and natural gas from the ground, including the search for underwater and underground natural gas fields or crude oil fields and the drilling of wells to recover oil and gas. This sector also treats the crude, removes water or waste and gets it ready for midstream and downstream processes. The midstream sector is involved in safely moving these natural resources from upstream to downstream facilities where they are processed into fuels and finished products used by consumers. This study will focus on the upstream sector where the onshore warehouse functions play significant roles in supporting the activities at offshore locations.

Currently, the industry still facing a gradual recovery in activities, especially for the upstream sector. As the oil price uncertainty and the latest Coronavirus disease (COVID-19) pandemic outbreak, it is a clear reminder to industry players to stay focused on business needs, explore and adopt cost optimization initiatives and become more competitive to sustain the challenges during this unpredictable period. The statistics in Figure 1 show the Brent crude oil price (average monthly) fell beginning in January 2020 from USD67.31 per barrel to the lowest value of USD18.38 per barrel in April 2020 with a total price drop of 72.7%. The price rises gradually in quarter 3 of 2020 and remains stagnant at USD40 per barrel towards year-end.

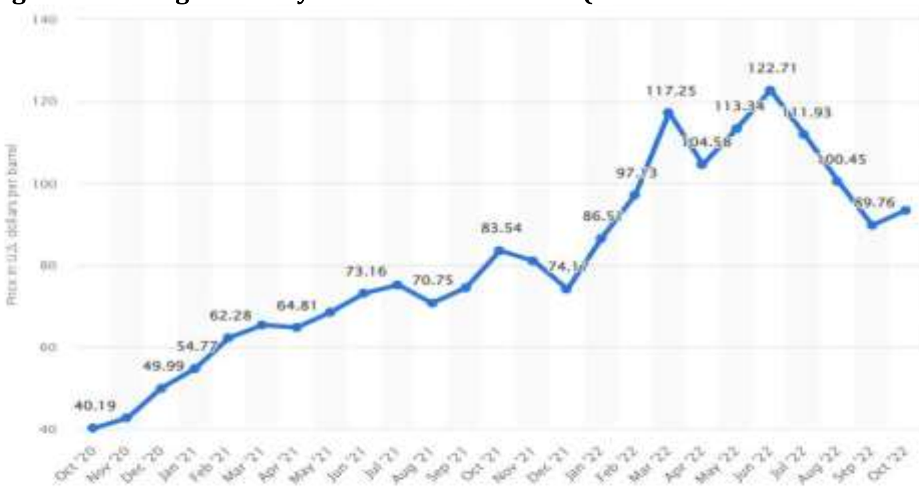
Even though the crude oil price showed improvement in early 2021 and rose between USD80 to USD90 per barrel in 2022 post-pandemic (refer Figure 2), global supply chain uncertainty and prolonged Russia-Ukraine war conflicts may have risk and impact on current business strategy and practice. Considering the historical trend of economic downtime, business resilience is essential to ensure the company can absorb and adapt to a changing environment to achieve its objectives and deliver the products and services as per requirements during any market situation.

Figure 1: Average Monthly Brent Crude Oil Price (October 2019 - October 2020)



(*Source: https://www.statista.com/statistics/262861/uk-brent-crude-oil-monthly-price-development/)*

Figure 2: Average Monthly Brent Crude Oil Price (October 2020 - October 2022)



(*Source: https://www.statista.com/statistics/262861/uk-brent-crude-oil-monthly-price-development/)*

Most of the countries in this region have their own National Oil Company (NOC) which plays a vital role in managing the entire oil and gas resources and is responsible for developing and adding value to these resources. The country's wholly owned company often provides the major percentage of revenue and contributes a significant amount towards the national Gross Domestic Product (GDP).

In Malaysia, the term "upstream business companies" refers to PETRONAS-licensed enterprises that specialize in Oil and Gas Services and Equipment (OGSE). Malaysia Petroleum Resources Corporation (MPRC), an agency under the Ministry of Economic Affairs (MEA), has initiated and published the OGSE100, a list of Malaysia's top 100 OGSE companies rated by revenue from a total of 1,641 OGSE enterprises nationwide. The ranking establishes the industry's benchmark for how well each company is performing in the oil and gas market despite recent obstacles.

Regionally, Malaysian players were more affected by Asian market movements, with slower growth of 6.4% compared to 24.9% for their counterparts. According to an MPRC study and analysis published in November 2019, the total revenue of the top OGSE100 companies decreased by 2.2% to RM55.2 billion in FY2018. The lower crude oil price in 2020 increases the challenges for enterprises to be resilient and react to unanticipated developments, as well as sustain and remain competitive in the sector.

The company in this study (hereafter called the "XYZ" company, due to confidentiality requirements) is a leading services provider for operations and maintenance (O&M) of the offshore facilities in the upstream industry. Since its establishment in 2012, XYZ has been awarded contracts for O&M of offshore facilities, with a total project of more than 10 from 5 different clients (which own the asset or operate the oil and gas field) within Malaysia territory.

As an emerging service provider in the industry, XYZ faces a few business challenges. Some of these challenges include but not limited to:

- dynamic environment in fulfilling client requirements and contract obligations.
- low-cost operations with business optimization.
- flexibility to respond to business risks and opportunities.
- limited size of organization (manpower and resources); and
- capital investment for system and technology.

To compete in such a demanding environment, the overall supply chain elements connecting onshore activities and offshore operations need to be well-managed including its supply chain planning, contracting strategy, sourcing-to-delivery activities and warehouse operations. Therefore, as per the scope of this study, the supply chain manager and warehouse team must ensure the warehouse operates efficiently to fulfill the contract obligation, providing the responsiveness as required by projects/clients and at the same time controlling the cost to be competitive within the industry.

Similarly, to other OGSE companies, efficient warehouse operations and adequate warehouse space are required to ensure smooth material handling and good inventory management for maintenance, repair and overhaul (MRO) related spares to offer reasonable responsiveness to upstream business demand. It is part of a common preventive measure to avoid unplanned equipment downtime due to stock-out of mission-critical parts and spares. In most cases, these organizations are willing to spend some cost by allocating more resources (including warehouse space) purchasing extra safety stock and keeping the inventory in hand, rather than incurring costs due to the inability to fulfill the client's request and losing future business opportunities.

To accommodate the demand from offshore facilities and support daily operations and materials handling, physical warehouse facilities at onshore supply bases have been established in addition to office-based activities at headquarters, by client requests. These warehouses function as transit centers, storing materials that are received from vendors before they are loaded onto ships bound for offshore destinations. By the project requirements of each client, the materials managed include equipment, spare parts, and consumables that are requested by frontline personnel at offshore sites.

To optimize space utilization and further improve warehouse efficiency, it is imperative to implement the most recent technological innovations. Implementing AI-powered inventory management systems, utilizing IoT-enabled sensors for real-time monitoring, and investing in automated storage and retrieval systems (AS/RS) are all part of this solution. Ultimately, these technologies can contribute to cost savings and enhanced operational efficiency by reducing manual labor, improving accuracy, and optimizing storage space.

Bottom line, the company's warehouse should be able to fulfill its critical role as an onshore logistics hub integrating onshore supplies and offshore demand for ongoing oil and gas facility O&M activities to build a better upstream service sector. Therefore, this study aims to understand the current setup and concerns on warehouse space utilization optimization for service companies in the oil and gas industry, specifically under upstream business.

2. Literature Review

The existing literature shows that there are limited studies on warehouse operations particularly for companies dealing with O&M of the offshore facilities, particularly in Malaysia. Most of the previous studies concentrate on operations and management of warehouses for the manufacturing industry and business operations for logistics and distribution centers.

Despite an increase in warehousing research papers over the previous fifteen years (Koster, Johnson & Roy, 2017), many studies have focused on specific topics such as routing, layout, order picking, and automation. With the recent rise in consumer demand for e-commerce sales and virtual shopping platforms, the warehouse and logistics industry has mostly involved retail business activities. The impetus for this study stems from the fact that the upstream industry's warehouse setup and operations continue to rely on traditional rule-of-thumb and a lack of strategy.

The study conducted by Davarzani & Norrman (2015) suggests relevant warehousing research in the future for both academic development and practitioners' needs. The scope is limited to warehouse operations and internal support activities such as warehouse design, performance evaluation, human resource management, as well as direct interfaces to other departments or companies from a logistics and operations management perspective. However, this research does not include space utilization review and inventory management-related issues.

A complete review of warehouse operation, warehouse design, and performance evaluation has been presented, based on a previous literature study conducted by Gu, Goetschalckx, and McGinnis (2007, 2010). The difficulties are categorized based on the fundamental warehouse functions to establish a meaningful connection between academic researchers and warehouse practitioners. Nevertheless, this literature analysis is focused on publications that were published before the year 2000. There are significant disparities in the technologies used in warehouse operations 30 years ago, particularly in terms of resource management, inventory storage tactics, and material handling techniques.

Regarding this gap, recent studies have been conducted to enhance our understanding of how warehouse operations and design are influenced by the shift towards integrated omni-channels (Kembro, Norrman & Eriksson, 2018) and to survey warehousing strategies in the e-commerce era (Boysen, Koster & F Weidinger, 2019). There is a need for further research on current warehousing strategies, particularly during and after the COVID-19 pandemic. Logistics and supply chain managers want the most recent study on warehouse operations to effectively address the current issues in the developing logistics and warehousing industry.

Davarzani and Norman (2015) also proposed that there exists a substantial disparity between the number of studies employing a modelling method limited by assumptions and those grounded in the intricate reality of warehouses. Further investigation is needed in this field due to the dearth of empirical research, necessitating additional case and action research studies in the future. The study conducted in real-case situations and its resulting findings may directly assist practical applications, aiding the research community in gaining a deeper understanding of the difficulties linked to warehousing. This suggestion pertains to a case study that employs explanatory and descriptive research methods. The study utilizes both quantitative and qualitative data to investigate real-life warehouse scenarios. It involves observing and analyzing events or processes to collect and report data about the specific event or situation.

Davarzani and Norman (2015) argue that further empirical research is necessary to comprehensively comprehend and capture the intricacies of the actual world. The authors suggested that normative studies, which entail prescriptive theory, should be supported by practical applications to benefit both academia and practice. These applications should be founded on postulates, deals, assumptions, or values. Furthermore, the article indicated that by utilizing two approaches, namely a literature review and analysis of practitioners' perspectives, the suggested agenda for future research should address both the observed deficiencies in the existing literature and consider feedback from the industry. For this specific research, the planned method will include conducting interviews with individuals who are directly involved in the research topic, making observations at the research location, and reviewing relevant material. These activities will focus on gathering qualitative data. Subsequently, quantitative data analysis and modelling simulation studies will be conducted to support and strengthen the qualitative findings, providing valuable insights for both academic and practical applications.

Based on another prominent literature by Bartholdi & Hackman (2019, 2008) on warehouse design and operations topic, most current warehouse practices are based on rule-of-thumbs, industry benchmarking and operations-driven setup. This practice can cater to the essential needs of warehouse operations, but it will lead to operational issues when the requirements and complexity increase in the long run. The literature suggested that mathematical models and simulation from the warehouse records and data will be able to help the practitioners tune their warehouse operations according to the business needs in meeting customer requirements. In line with this finding, the researcher will observe the current warehouse practice and gather the operations data, particularly on space allocation and utilization, material movement and inventory storage status for further analysis. Based on historical data analysis results, this study will present how the simulation model is developed for variable testing and process-based simulation on multiple scenarios. The results and findings from both historical data analysis and simulation models are expected to provide some recommendations for optimizing warehouse operations.

Bartholdi and Hackman (2019) also suggested that there are a few areas of concern for consideration about the good setup of warehouse operations. This includes but is not limited to:

- Warehouse issues, resources and processes
- Warehouse layout and slotting area
- Order-picking path and material handling
- Warehouse system and automation

Regarding warehouse layout, Bartholdi and Hackman (2019) suggested that storage models will play a significant role in determining layout design and allocation. A suitable warehouse layout should increase the throughput, reduce costs, improve the service provided to the customers and provide better working conditions (Richards, 2017). As a fact, the total area of warehouse space and its location will determine the fixed warehouse cost and any increase in space rental tariff will impact overall operations cost, where the comprehensive analysis of the different layouts provides opportunities to improve both ergonomics and economic performance (Calzavara, Glock, Grosse, Persona, & Sgarbossa, 2017). Thus, this study will explore the potential optimization of warehouse space allocation and possible improvement in space utilization will bring value to every cent spent on the warehouse setup.

Based on studies by Perera, Mirando, & Fernando (2022) and Bartholdi and Hackman (2008), allocating space in a forward pick area of a distribution center for small parts where the forward pick area of a distribution center is a cache of conveniently located products from which order pickers can quickly draw, but which must be replenished from bulk or reserve storage. Similarly, a temporary storage area for transit material is allocated near the receiving area and loading area to reduce material transfer handling duration and consolidation time. However, this paper discussed the stocking strategies commonly used by distribution centers where daily material transaction volume is relatively high compared to the material movement for the warehouse operation in this study. The service companies in the upstream business depend on the supply vessel scheduled for shipping out the material to offshore facilities (like a regional warehouse in the distribution center model). Normally the supply vessel departs from the onshore supply base to the offshore location with a frequency between 1 to 2 weeks each.

As cited by Koster, Johnson & Roy (2017) in their paper, optimizing space utilization is one of the main goals of warehouse design and operation. One of the findings suggests block-stack storage as an inexpensive storage system widely used in manufacturing operations for storing pallets, where this form of palletized storage does not require any type of storage equipment, and instead loaded pallets are placed directly on the floor and built-up in stacks to a maximum level permitted by the safety design. As earlier described by Pham, Nguyen, Doan, Thai, & Nguyen, (2019) and Derhami, Smith and Gue (2016), in a relevant paper specific to block stacking warehouses, they propose mathematical models to obtain the optimal lane depth using a simulation model to analyze the layout performance with stochastic input parameters.

Previous studies (Ferreira & Reis, 2023; Toorajipour, Sohrabpour, Nazarpour, Oghazi & Fischl, 2021). suggested warehouse management in the oil and gas industry has been transformed by artificial intelligence (AI) and machine learning, which have both offered substantial advantages and potential disadvantages. AI-powered systems can accurately forecast demand and optimize storage space, resulting in increased efficiency and reduced costs. Machine learning algorithms can guarantee the efficient positioning of items, thereby reducing the likelihood of equipment damage and improving safety. Real-time inventory visibility is facilitated by IoT-enabled sensors, which reduces the risk of equipment loss and enables proactive management.

Furthermore, these sensors can monitor environmental conditions, thereby preventing the deterioration of sensitive materials and guaranteeing adherence to safety regulations. Robotics and automation optimize material handling, thereby decreasing the likelihood of human injury and enhancing productivity (Tikwayo & Mathaba, 2023). On the other hand, cloud-based warehouse management systems (WMS) facilitate data-driven decision-making and provide real-time data, resulting in enhanced efficiency, regulatory compliance, and optimized space utilization (Tubis & Rohman, 2023).

These available literature materials are useful but only provide generic findings and solutions when it comes to explaining the warehouse operations for oil and gas companies serving the upstream industry. This case study to investigate and provide an explanation of warehouse setup, issues in space utilization and influencing factors on performance is expected to suggest possible optimization of warehouse operations. The outcome of this study will also contribute to the research knowledge as well as in practical terms specifically to warehouse operations and overall supply chain management.

3. Research Methodology

The study employs a single-case study approach and uses a multi-method research process including semi-structured interviews, site observations and documentation review as the primary method of data collection. Based on this qualitative research approach, this study will investigate and seek an understanding of how the warehouse operations are being executed by XYZ company as services offered to their clients, involved in the oil and gas industry in Malaysia.

Three data collection methods used in this study are:

- Interviews,
- Field observation, and
- Document review and analysis.

This present study aims to understand the current setup and concerns on warehouse operations for service companies in the oil and gas industry, specifically under the upstream business as explained in the previous section. These data collection methods are chosen after considering the best possible method that can provide rich data. These methods also are the best possible method that can be able to help answer the research questions. Out of these three methods, data were mainly gathered through in-depth interviews. The variety of data collection methods enables the researcher to cross-examine the data to check the consistency of the findings, which is useful to support the study analysis (Long & Johnson, 2000; Denscombe, 2010).

One of the critical key instruments to unearth multiple perspectives amongst the participants, the researcher applies semi-structured interviews, particularly in understanding the warehouse setup and its functions as well as the factors and issues surrounding the warehouse operations. As opposed to a strictly organized interview method, semi-structured interviews provide flexibility to include extra or unstructured questions throughout the interview sessions.

Since the participants of this study vary in terms of their job level (from supervisory to assistant roles) and job responsibility, a different way of questioning styles and content is appropriate to gain each participant's unique experiences, thoughts and stories (Rubin & Rubin, 2012). The interview length varies from 15 minutes to more than 1 hour, with an average length of 30 minutes per interview. A unique code was assigned to each participant to ensure that the individuals and the company remained anonymous in this study, and this was agreed upon before each interview was conducted. Below is the brief profile of the participants involved in this study:

Table 1: List of Interviewees, Roles and Functions at XYZ company

Code	Level	Roles	Function
IP#1	Supervisor	Warehouse & Logistics	Team leader overseeing overall warehouse operations, logistic planning and material movement coordination
IP#2	Executive	Warehouse	Warehouse operations, compliance and inventory management
IP#3	Coordinator	Warehouse	Warehouse receiving and material storage
IP#4	Coordinator	Logistics	Material consolidation, loading coordination and backload handling
IP#5	Assistant	Warehouse & Logistics	Material receiving, storage, consolidation and loading/backload handling
IP#6	Assistant	Administration	Documentation preparation and maintenance records

In addition, field observations were conducted at XYZ company's warehouse locations, in the form of a guided tour to obtain information that could not be covered during the interviews (Yin 2009). Field observations allow the researcher to visualize and learn about physical warehouse setup, process flow and overall warehouse operations. During the field observation also, the researcher can crosscheck and validate the information received from the participants (Tracy, 2020; Sandelowski, 2000), whether it indeed matches the actual activities happening at the warehouse facility. In the event of information uncertainty or any doubt about the process or events at the site, the researcher can seek out further verbal clarification immediately.

During the visit to the company's warehouse facility at the supply base area, the researcher was given access to the warehouse office, goods receiving and storage area. This provides first-hand, real-time information on the overall material flow process of purchased items from material receiving until it was accepted and allocated by relevant projects and facilities. During the observation, field notes were written and supported by photograph images taken within the premises upon agreement by the warehouse supervisor. However, any company logo or information must be removed (hidden) to ensure the company remains anonymous in this study.

Table 2: XYZ Company's Site Observations and Activities

No	Location	Activities and Processes Observed
1	Receiving Area	Material unloading, receiving, inspection & acceptance
2	Transit Storage Area	Material transfer, segregation and tagging
3	Storage Racking Area	Material storage, identification and preservation
4	Consolidation & Loading Area	Offshore container handling and material preparation
5	Warehouse Office	Documentation updating and record keeping

The third data collection method used to further assist the researcher in understanding the supply chain process and its warehouse operations was by reviewing relevant documents produced, referred and implemented by XYZ company. This includes XYZ company procedures, guidelines, warehouse reports and records to support the data collected from interviews and observations (Tracy, 2020; Yin, 2009).

This technique has been employed for the data collection process in this thesis and is based on some justifications. First, the review of relevant documents i.e., warehouse procedures gives a better understanding of the company's warehouse standard operations and procedures, including a fundamental technical understanding of how the warehouse was operated for upstream business, especially for offshore facility's operation and maintenance activities. The document also describes the process flow and various roles and responsibilities of warehouse personnel to ensure the compliance and integrity of supply chain processes for the company. Based on this understanding, the data collection process through interview and observation was facilitated as the researcher was able to confirm and corroborate issues.

Some of these documents are published by the company and some were only released to researchers specifically for this study with the permission of the participants (Refer to Table 3).

Table 0: List of XYZ company's Documents Obtained for the Study

No	Documents	Information / Scopes Reviewed
1	Warehouse Procedures	Material process flow, warehouse personnel roles, responsibilities and functions.
2	Material Movement Report	Material information, quantity, type (local or bonded) receiving date, loading date and project status.
3	Inventory Report	Material information, quantity, storage location, movement (in/out) and project remarks.
4	Supply Vessel Records	Vessel name, movement data, location to and from.
5	Audit Report	Operational findings and suggestions for improvement.

4. Results

The first part of this section captures findings on physical setup and its process flow as well as operational challenges and influencing factors which will provide some discussion on the warehouse operations for the specific industry. In addition, several factors affecting warehouse space utilization and how to address these factors to increase the utilization will be presented accordingly.

Warehouse Setup

The XYZ company's warehouse under the study was established in the year 2015 in Kemaman Supply Base (KSB), Terengganu (approximately 300km from Malaysia's capital Kuala Lumpur); where the area was gazetting as a bonded supply base for oil and gas business operations for Terengganu offshore project. The establishment was to handle the material purchased by the company on behalf of the client where it involves basic material handling including receiving, temporary storage and transfer to the offshore facility located approximately 200km from the onshore supply base.

After XYZ company was awarded a second project, the operations were relocated to the bigger warehouse to cater to the second contract requirements including storage of project inventory on behalf of the client. Since then, this warehouse has been expanded a few times to cater to requirements for additional projects (third and fourth). The warehouse function is becoming more complex as the requirements also cover consolidation of material for loading, logistics planning and inventory monitoring for operations spare items.

The latest warehouse expansion happened in 2018 where the warehouse has a proper office and layout including an allocated area for material receiving, loading and storage. As this study takes place, the current warehouse setup covers an area of 2,000 square meters (equivalent to 21,500 square feet) including a warehouse office, open space for receiving, temporary storage, loading and forklift movement and dedicated space for ten rows (aisles) of the 4-level racking system (in total 104 racking module). This setup was able to support material movement, handling and inventory storage for a total of five projects (for two contracts servicing two different clients). Table 4 below explains the details of the warehouse layout and its estimated space allocation.

Table 0: XYZ company's Warehouse Layout and Space Allocation

Area Type	Area Function	Est. Space (sqm)	Allocation
Operation Area	Receiving, storage and loading	400	20%
Storage Racking	Inventory 4-tier racking module	400	20%
Open Floor Area	Forklift movement zone/buffer	750	37.5%
Non-activity Area	Office, Counter, Utility, etc.	450	22.5%
Total Area (sqm)		2,000	100%

During a visit to the warehouse location, the researchers found that the warehouse was divided into 2 physical facilities. The first facility (Door 1) with an approximate total space of 800 sqm caters to a warehouse office, receiving counter, receiving area for small material (in boxes), open operations area, and 14 racking modules

(1 row). The second facility (Door 2 and 3) with an approximate total space of 1,200 sqm caters to the main receiving area (material on a pallet), pallet transit area, loading area, forklift movement area and a total of 90 racking modules (9 rows). Figures 3 and 4. show the visual warehouse layout including its functional area location and physical arrangement.

Figure 3: Warehouse Overall Layout and Space Allocation (Door 1)

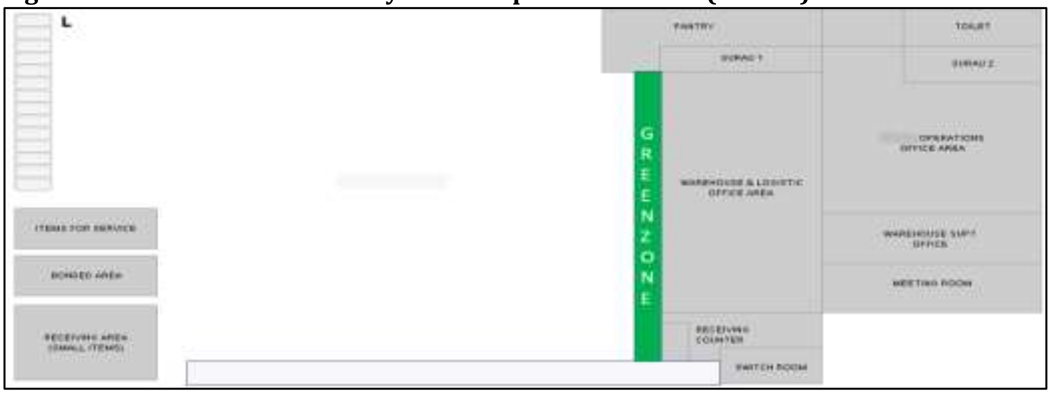
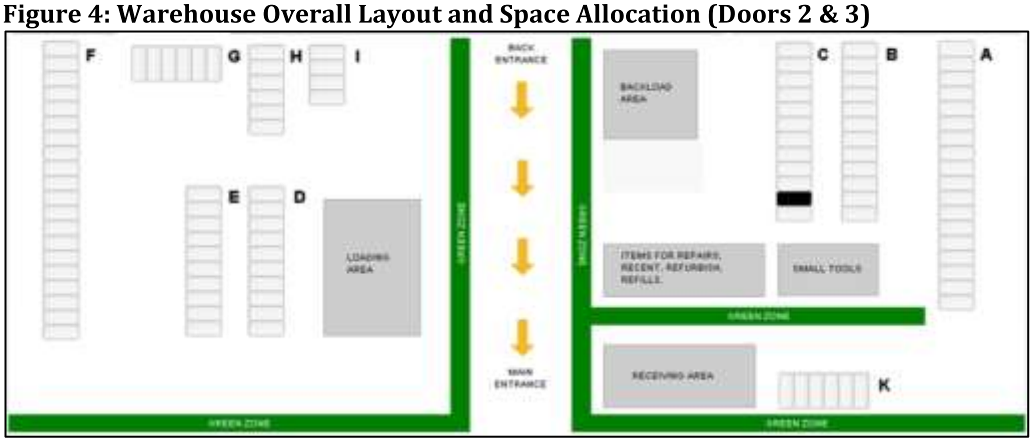
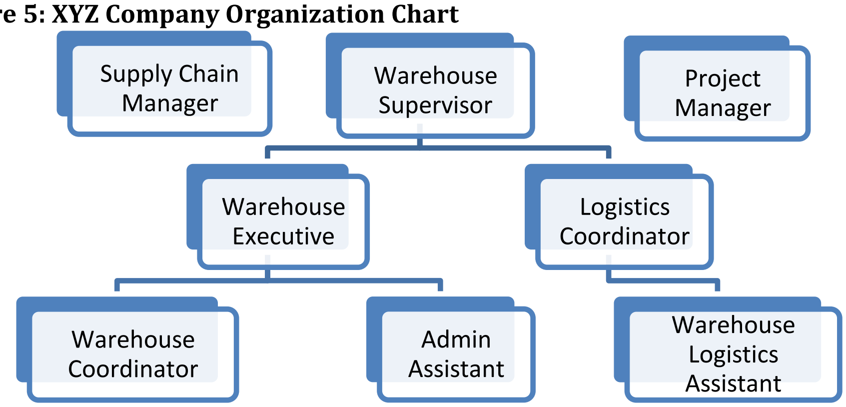


Figure 4: Warehouse Overall Layout and Space Allocation (Doors 2 & 3)



In terms of warehouse resources, the startup of basic warehouse operations employs two warehouse personnel to undertake the receiving and loading functions. As the warehouse function has expanded with more scopes defined under contract requirements, the manpower strength has been increased to cater to the operational tasks, administration and reporting to clients. Currently, the warehouse under study has a total of six personnel including one supervisor (as team leader). As per XYZ company organization chart (refer to Figure 5), the warehouse team reports directly to the supply chain manager and operationally reports to the operations department where all the daily project execution, monitoring and control is happening.

Figure 5: XYZ Company Organization Chart



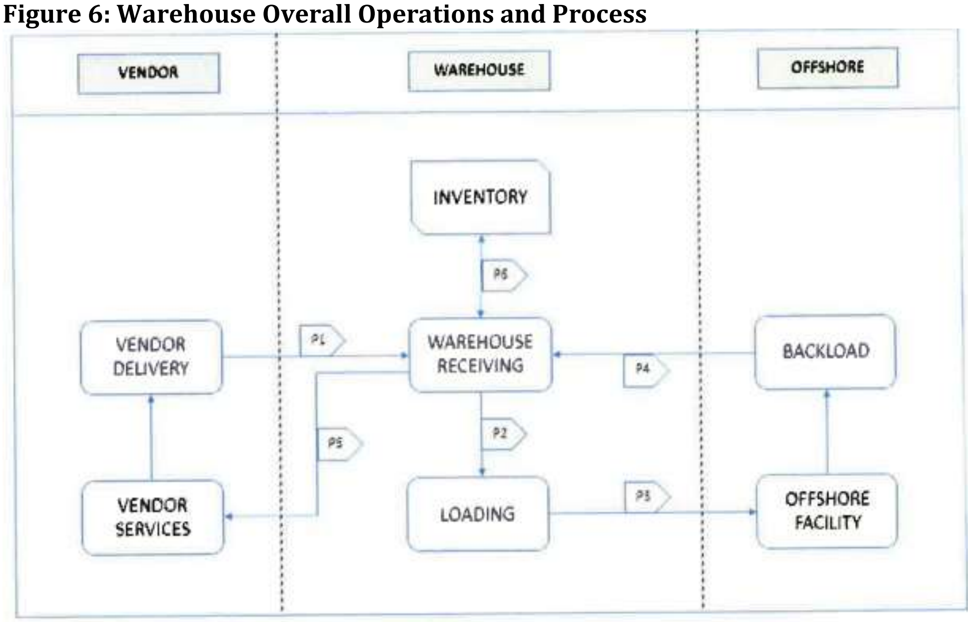
To support basic operations, this warehouse possesses basic material handling tools such as manual pallet jack, trolley, hand tools and packaging consumables. The advanced material handling equipment (MHE) such as forklift, crane and trailer (including equipment's operator) are provided by the supply base operator as chargeable services (pay per use as per timesheet) upon request from the company. As per rules defined by the supply base operator, the request for MHE shall be made one day in advance via the booking system (i.e., request to be made by 4.00 pm for the service to be available the next day at 8.00 am).

From a system perspective, the warehouse uses basic Microsoft Excel sheets as tools for recoding warehouse data including the material movement and its inventory listing. As updated during the interview, the company is currently developing an in-house warehouse management system to improve data recording and upkeep processes for better monitoring and reporting purposes. As part of the plan, this system will be extended to the headquarters office and offshore location for real-time information sharing and better visibility of materials to support the company's O&M activities at the site.

Warehouse Operational Process

During the interview, all participants explained the warehouse operations and their relevant processes by their respective functions. The warehouse operations can be divided into 3 main functions: material handling (receiving, transfer/transit and loading), material storage (inventory management) and logistics coordination (supply boat arrangement). However, the scope of this study only focused on material handling and storage where the processes happened within the company's warehouse space. The overall warehouse operations and process can be referred to as per Figure 6 below:

Figure 6: Warehouse Overall Operations and Process



Based on the above figure, the research scope only covers 3 processes (in oval shape) which include material receiving (Process P1), material loading (Process P2) and inventory material (Process P6). The details for each relevant process refer to the following:

Process P1: material receiving from vendor, inspection and acceptance by warehouse receiving, material handling and assigning to the allocated storage area by project and record updating.
Process P2: retrieval of material from the storage area, consolidation, preparing for material loading including packing and transfer of material into the container, container handling and shipping documentation and record updating.
Process P6: inventory material storage and preservation, material issuing in/out, inventory monitoring/updating and maintaining record/audit.

As the above process is defined in the company's Warehouse Procedures, the researcher has reviewed the documentation and found the activities explained by participants corroborate with the processes and functions defined in the procedures.

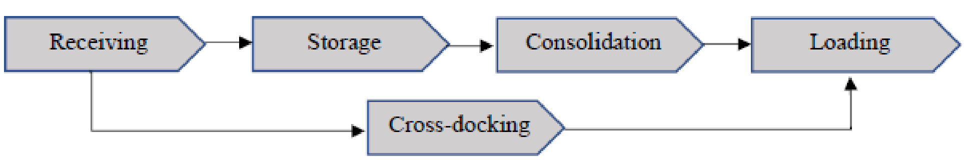
All the documentation for the above processes such as Purchase Order (PO), Delivery Order (DO), Commercial Invoice & Packing List (CIPL) and relevant material certificates are recorded and kept by the warehouse as project records for claim purposes and future references. Based on local authority requirements (Royal Malaysia Custom) for bonded supply base area, all documentation including Custom Form required to be kept by the warehouse office as evidence for audit and future purposes with minimum record retention of seven (7) years. The researcher also found that this is aligned with warehouse procedures which defined that the record retention of all documentation is seven years.

Factors Impacting Warehouse Space Utilization
In managing warehouse space and determining the functional layout, the Warehouse Supervisor and Supply Chain Manager need to identify the possible factors that impact the space utilization. The available warehouse area must be used in the best possible way so that the company will be able to do more with all the space on hand. Generally, the factors relevant to space utilization may include storage systems, as well as racking and pallet patterns. Based on interviews, site observation and documentation review conducted both virtually via desktop and physical process at the site, the current study has captured the applicable factors that affect the current warehouse space utilization.

Material Handling and Movement: Based on the warehouse setup explained in section 4.1, approximately 58% of warehouse space is allocated for material handling operation (20%) and open floor for forklift movement (38%). The space material handling operation includes the receiving area, loading area and temporary storage area for transit material while the forklift movement area includes a dedicated path for the forklift, green zone area and movement safety buffer between storage racking system. The utilization of this area mostly depends on the warehouse activities and its volume including incoming and outgoing materials.

From the interview, the material receiving happens almost every day and the volume (number of pallets) depends on the packing list provided by the supplier prior delivery process. The frequency of material deliveries depends on planned maintenance activities at the site and usually will be high within 2 to 3 days prior next supply boat schedule to the offshore location. In addition, the receiving volume will reach its peak when there are major planned maintenance activities (for example annual facility shutdown works) of certain projects. During site observation, the researcher found that the current receiving rate was minimal (less than five pallets a day) since the major maintenance work (integrated activities for 3 projects) had just been completed in previous months.

Figure 1: Material Handling Flow



The received material will be consolidated according to specific project and location 1 to 2 days prior loading date (Refer Figure 7). During this period, there are also instances where the material received in offshore containers belongs to a supplier for offshore work where this material is handled as per cross-docking operation. The loading schedule is planned by the logistics supervisor a month in advance based on logistic planning input from the client.

However, the final loading date is only made known to the company between 2-3 days in advance since the logistic scope i.e., supply boat to/from offshore location is determined by the client. as an order to transfer the material to a specific location (where consolidation is happened by project). Until the loading date is determined (as an order from the client), all transit material will temporarily occupy the open space allocated from the receiving date. Thus, the total transit time for each material (on a pallet) can be recorded as the loading date minus the receiving date plus 1 day (1st day receiving). Below Figure 8 explains the timeline of material flow from receiving date to loading date and how to calculate the duration of transit time (TT).

Figure 2: Material Transit Time

Transit Time, TT (in days) = (Loading Date – Receiving Date) + 1

Transit Time, TT

Receiving date	Temporary Storage	Consolidation	Loading data
August 1	August 1	August 12	August 14
Total duration, TT = (14/08 – 01/08) + 1 = 14 days			

Due to material volume received within a week varying by project and the loading date not being determined upfront, the warehouse implemented a pool area on a sharing basis for temporary storage of transit material instead of specific allocation by project. The labeling tag was used to identify each material detail (i.e., PO and DO reference) and its belonging to which project. This method enables better utilization of pool space to cater to various volumes of transit material for consolidation before loading. Based on site observation, approximately 250 square feet of open floor space has been allocated for this purpose and this area can accommodate up to 150 pallets at one time.

Inventory Movement: In terms of inventory management function, this XYZ warehouse stores materials that have been purchased by clients as maintenance spares onshore for operating facilities usage upon requirement in the future. These inventories are categorized as MRO materials which include but are not limited to equipment/spare parts (including pumps and motor), special tools (for turbine/engine maintenance work) and common maintenance consumable supplies (such as gaskets, bolts and nuts). Some spares with high value (such as spare equipment and special tools) are considered as assets for the project.

As captured from the inventory data for Quarter 3 2022, Table 5 shows that the number of SKUs for spare equipment and parts dominates 61% of the inventory list followed by special tools (32%) and consumables supplies (7%). Based on input from the inventory management focal, most of the materials stored on the racking since the year 2018 are considered very slow-moving. The inventory retrieval only happens when there is a material request from the material coordinator at the site.

Table 5: Inventory Categories, Total SKU and Volume

Type of Inventory	No. of SKU	Volume %
Equipment / Spare Parts	221	61%
Special Tools	115	32%
Consumable Supplies	25	7%
Total SKU (Q3 2022)	361	100%

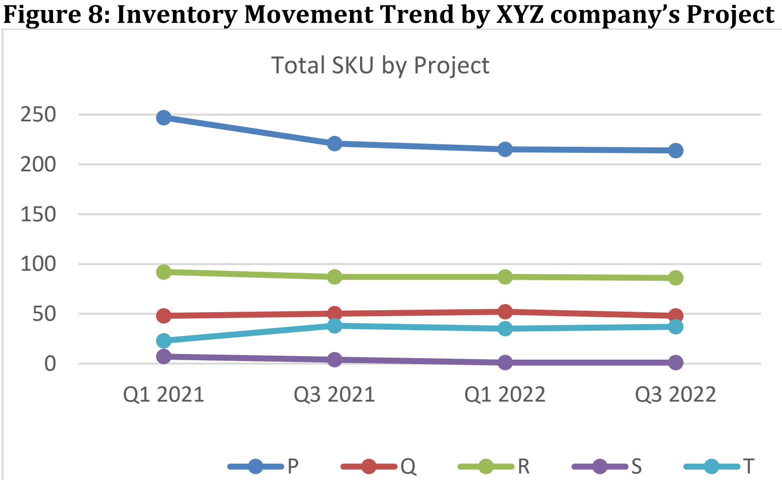
Table 6 shows a total number of SKU changes for a total duration of 18 months from March 2021 (Q1 2021) until August 2022 (Q3 2022), where the change in data presented based on bi-quarterly (e.g., Quarter 1, Quarter 3, 2021 and Quarter 1, Quarter 3, 2022). From the table also, the initial total SKUs of 418 in Q1 2021 is reduced to 361 in Q3 2022 with a total SKU movement rate of 14%. However, if the total SKU is segregated by project (Project P, Q, R, S, and T), each project shows a different trend. For instance, SKU for Project P has decreased by 23% (58 SKUs) and inversely SKU for Project T has increased by 61% (14 SKUs). Further reference made with inventory management focal clarified that there are surplus materials backloaded from offshore for Project T for storage on racking.

Table 6: Total SKU by Project

Project	Q1 2021	Q3 2021	Q1 2022	Q3 2022
P	247	215	190	189
Q	49	50	49	48
R	92	87	87	86
S	7	1	1	1
T	23	38	35	37
Total SKU	418	391	362	361

Figure 8 shows a visualization of inventory movement trends by each project for the captured inventory monitoring duration of 18 months. About 52% of SKUs stored on the racking belong to Project P and they were inherited from the client during the project award (since year 2018). In addition, most of the materials stored on the racking were found with very slow-moving rates of 6% to 7% per year. The space allocated for inventory (which is about 20% of warehouse space) is considered fully utilized since the racking is permanently installed on the warehouse floor. Further utilization analysis by racking volume (space multiplied by height) to determine the actual capacity utilization will be explained in the next section under quantitative findings.

Figure 8: Inventory Movement Trend by XYZ company's Project



Warehouse Space Availability: As the previous section explains on few factors impacting warehouse space utilization, the researcher also captures some findings and concerns with regards to warehouse space availability based on information gathered during interviews and site observation. Based on the warehouse setup background and expansion happening earlier as described in Section 4.2, it was found that there are a few concerns which considered external factors impacting the warehouse space utilization. These factors are detailed below:

Warehouse space availability: There is limited space available to be leased within the supply base area, where priority is given to big oil & gas companies and offshore asset owners (clients).
Warehouse space suitability: Not all available space is suitable to cater to requirements for the company's warehouse operation, especially with a significant amount of inventory required to be stored as per contract obligation.
Business decision: The management prefers to operate the warehouse in a single-point location (including the warehouse office, operation area and storage) for better monitoring, management and cost efficiency.

Since the warehouse was established within the bonded supply base area, the available warehouse space depends on the offer given by the landlord. Based on historical events of warehouse relocation and expansion, the available and suitable spaces are limited and offered on a first come first served basis. For instance, this warehouse operates in two physical buildings (Door 1 is separated from Door 2 and Door 3) as explained in Section 4.2.1. This is happening to meet the company's management direction to have efficient operations of the warehouse at a single location (in this case the closest space available for lease).

Discussion

Generally, the main goal of warehouse operations is to meet the demands and specifications of customers while making efficient use of the space, tools, and labor available in the warehouse. The corporation will receive and load the necessary goods in time for replenishment on the store at the offshore site for the planned O&M activities, according to this analysis, if warehouse operations are efficient.

The way a warehouse is set up at the beginning usually dictates how it will be used. The warehouse structure for the organization under investigation is based on a basic configuration with a lean operations team to complete the business function, based on results reported in the previous chapter. It is advised that the company set up its first warehouse activities to achieve its contractual obligations to complete the fundamental project needs. This is especially important as a transit point for the consolidation of materials at the onshore supply base before they are transferred to the offshore location.

However, as more contracts have been secured, the warehouse operations require expansion (physical & resources) and the project requirements becoming more complex, i.e., client's spares for storage, inventory management & reporting. Client's requirements are more stringent, especially with regards to new regulations by local authorities and compliance audits by governing bodies, i.e., new Custom regulations on the declaration for local goods before entrance to the supply base area.

In terms of facility and location, this warehouse is located within the preferred location for handling and storage of material for offshore operations. However, there are some limitations and relevant challenges for warehouse facilities located in the gazette supply base area (i.e., space availability against suitability, rules and regulations for bonded against non-bonded area). Contrarily, the company may opt to set up the warehouse outside the supply base without these limitations but may incur other possible operations challenges (i.e., additional cost for building construction/initial setup and logistics cost from the warehouse into the supply base area).

In terms of resources, this warehouse employs a basic operations structure which is commonly implemented to meet lean operations management. The warehouse personnel employed are adequate to perform the basic function of the warehouse from incoming material receiving to outgoing material loading. However, there are some concerns about manpower capacity and capability which limits the intended output of warehouse operations. In addition, the risk of overloading tasks assigned to these personnel may lead to unnecessary work pressure, an unhealthy working environment and unsafe working conditions.

This study also discovered that the warehouse still uses a basic spreadsheet to record transactional data and inventory levels. This arrangement duplicates manual data entry and may compromise warehouse information flow accuracy. Instead, the corporation may design its own WMS, including receiving and loading. The company might also subscribe to or outsource a better warehouse management system from a recognized third party that integrates with its supply chain system to maintain material requisition and PO issuance continuity.

Warehouse procedures, established by management, guide staff inefficient process execution. The warehouse procedures outline basic warehouse operations flow with appropriate roles and responsibilities of warehouse staff. The organization accepts this practice because there are no non-conformance findings from past audits.

Warehouse space utilization assesses how efficiently the warehouse stores goods and inventories. If the proportion is low, the warehouse may be larger than needed due to faulty inventory storage layout or space allocation based on demand predictions. According to the definition, warehouse space utilization is the percentage of warehouse or facility space used. This derives the formula as below:

$$\text{Space Utilization \%} = (\text{Amount of Warehouse Space Used} \div \text{Total Warehouse Space}) \times 100$$

Based on the above formula, the warehouse space is considered in use when the materials occupy the space for a specific time. In this study, it was found that 58% of total warehouse space was allocated for forklift movement and operations (material receiving, transit storage and loading activity) while 19% was installed with storage racking. Thus, only 77% of floor space is available for warehouse operations purposes and the remaining 23% was a non-activity area which has been excluded from the calculation. From this finding, it was found that approximately 25% of the floor space has been fully utilized for racking and the utilization of balance 75% depends on daily activity volume and material movement trend. Refer to Table 7 for calculation details.

Table 7: Calculation for Warehouse Space Utilization

Area Type	Calculation	Space Utilization %
Storage Racking Space	19% ÷ 77% × 100 = 24.7%	25%
Operation Space	21% ÷ 77% × 100 = 27.3%	75%
Movement Space	37% ÷ 77% ×100 = 48.0%	

5. Managerial Implications and Recommendations

This study provides practical guidance for warehouse management and supply chain practitioners in identifying the aspects and difficulties related to warehouse operations. This study also aids practitioners by examining the correlation between these elements and difficulties and the success of warehouse operations, particularly in terms of warehouse space utilization.

This study demonstrates the significance of establishing a warehouse to the specific needs and service requirements of a firm. Furthermore, the successful and efficient execution of warehouse activities heavily relies on the proficient administration of warehouse resources.

This study provides a baseline understanding of warehouse operations for service companies in the upstream industry. The findings and outcome from this study may provide guidance and opportunities for future research in the following areas:

- Although the study has identified two main factors impacting space utilization, the level of importance of each of the factors is not defined as the objective of this study is only to identify and explore the factors.
- A larger scale study using a quantitative survey instrument involving more participants from various stakeholders can be carried out to further investigate more factors and the interrelation between these factors. The quantitative survey also may discover new factors or issues that have not been identified in this study.
- For future research, further study could be carried out about warehouse layout design for warehouse set up within the same industry, with the expectation to determine the effectiveness, advantages and disadvantages of each layout. In addition, a similar study was to determine the impact of inventory management strategy for similar warehouse operations, where categorization and classification of inventory were made before organizing and storing them on allocated racking.

Conclusion

This study enhances the comprehension of warehouse operations for service companies, namely those involved in providing operations and maintenance (O&M) for offshore facilities in the upstream business. This study enhances our understanding of the specific requirements and approach for setting up warehouse operations to fulfill contractual obligations. This study is one of the first to examine and document how the organization determines the fundamental warehouse activities that can meet the business requirements while ensuring that the setup and functionality remain cost-effective. This study also revealed the diverse aspects and difficulties that impacted the utilization of warehouse space and the performance of operations.

The results of this study make a valuable addition to the existing information about how the arrangement of a warehouse, the process of handling materials, and the methodology of storing inventory impact the utilization of warehouse space. The warehouse in question utilizes a combination of a distribution center (DC) layout and an inventory storage layout. The transit material is managed according to the DC concept, while the inventory is housed on a 4-tier racking system. According to the researcher's expertise, this study is the first of its kind to be undertaken in both environments, offering significant insights to warehouse operations and supply chain management professionals.

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