# ANALYSING ROLE OF TECHNOLOGY SYSTEM, STORAGE DESIGN AND MATERIAL HANDLING TO IMPROVE WAREHOUSE OPERATION ACCURACY



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# ABSTRACT

Warehouse operation inaccuracy remains a critical issue in manufacturing companies, often resulting in operational inefficiencies, production delays, and increased costs. This research analyses the extent to which technology system, storage design, and material handling influences inventory accuracy in manufacturing warehouses, with a specific focus on facilities located in Kulim Hi-Tech Park, Malaysia. This research contributes positively to the manufacturing industry by significantly improve inventory accuracy. Enhanced accuracy leads to greater operational efficiency, cost savings, and more informed decision-making. The findings also support Industry 4.0 adoption by demonstrating the value of digital systems like RFID and WMS. Furthermore, the study provides practical insights for benchmarking, policy development, and workforce training, ultimately helping manufacturers optimize their warehouse operations and remain competitive. A total of 40 manufacturing companies operating within Kulim Hi-Tech Park were identified as the sampling frame for this study. Based on the Krejcie and Morgan (1970) table, the planned sample size was determined to be 36 respondents, representing personnel involved in warehouse and inventory operations across these companies. A quantitative research approach was employed, utilizing structured questionnaires distributed to supply chain professionals and warehouse personnel within selected manufacturing companies. The study applied descriptive statistics to evaluate relationships among key variables. The findings reveal that the implementation of system applications such as RFID, barcode systems, and WMS significantly enhances inventory visibility and tracking. Additionally, optimized storage design characterized by layout planning, slotting strategies, and accessibility contributes positively to inventory accuracy. Furthermore, effective material handling, including automation, and standardized operating procedures, are also associated with reduced inventory errors. The implications extend to industry practitioners aiming to improve operational efficiency and to policymakers advocating for Industry 4.0 readiness in manufacturing logistics. Future research should explore longitudinal data and include qualitative insights to enrich the understanding of human and organizational factors.

Keywords: System Applications, Storage Design, Material Handling, Inventory

# ABSTRAK

Ketidaktepatan operasi gudang kekal sebagai cabaran kritikal dalam pengurusan syarikat pembuatan, yang sering mengakibatkan ketidakcekapan operasi, kelewatan pengeluaran, dan peningkatan kos. Kajian ini meneliti sejauh mana sistem teknologi, reka bentuk storan, dan amalan pengendalian bahan mempengaruhi ketepatan inventori dalam gudang pembuatan, dengan tumpuan khusus kepada fasiliti yang terletak di Kulim Hi-Tech Park, Malaysia. Kajian ini menyumbang secara positif kepada industri pembuatan dengan meningkatkan ketepatan inventori secara signifikan. Ketepatan yang lebih tinggi meningkatkan kecekapan operasi, mengurangkan kos, dan menyokong proses membuat keputusan yang lebih tepat. Penemuan kajian ini juga menggalakkan penerapan Industri 4.0 dengan menunjukkan keberkesanan sistem digital seperti RFID dan WMS. Selain itu, kajian ini memberikan panduan praktikal untuk penanda aras, perumusan dasar, dan latihan tenaga kerja, sekali gus membantu pengilang mengoptimumkan operasi gudang dan kekal berdaya saing dalam landskap industri yang semakin berkembang. Sebanyak 40 syarikat pembuatan yang beroperasi di taman tersebut telah dikenal pasti sebagai kerangka pensampelan. Berdasarkan jadual saiz sampel oleh Krejcie dan Morgan (1970), sebanyak 36 responden telah dipilih, terdiri daripada kakitangan yang terlibat dalam operasi gudang dan inventori. Pendekatan penyelidikan kuantitatif telah digunakan, dengan pengedaran soal selidik berstruktur kepada profesional rantaian bekalan dan kakitangan gudang di syarikat yang terpilih. Statistik deskriptif dan analisis korelasi telah digunakan untuk menilai hubungan antara pemboleh ubah utama. Dapatan kajian menunjukkan bahawa pelaksanaan aplikasi sistem seperti RFID, sistem kod bar, dan sistem pengurusan gudang (WMS) secara signifikan meningkatkan keterlihatan dan penjejakan inventori. Selain itu, reka bentuk storan yang dioptimumkan, termasuk perancangan susun atur, strategi slotting, dan kebolehcapaian yang baik, menyumbang secara positif kepada ketepatan inventori. Amalan pengendalian bahan yang berkesan, seperti automasi dan prosedur operasi piawai, juga didapati dapat mengurangkan kesilapan inventori. Implikasi kajian ini adalah penting untuk pengamal industri yang ingin meningkatkan kecekapan operasi serta untuk pembuat dasar yang menyokong kesiapsiagaan Industri 4.0 dalam logistik pembuatan. Kajian pada masa hadapan disarankan untuk menggunakan data longitudinal dan menggabungkan pendekatan kualitatif bagi memperkayakan pemahaman terhadap faktor manusia dan organisasi yang mempengaruhi ketepatan inventori.

Kata kunci: Aplikasi Sistem, Reka Bentuk Storan, Pengendalian Barang, Inventori

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Manimaran Raman

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## LIST OF ABBREVIATION

| | |
|---|---|
| ERP | Enterprise Resource Planning |
| RFID | Radio Frequency Identification |
| WMS | Warehouse Management Systems |
| GDP | Gross Domestic Product |
| JIT | Just-In-Time |
| MIDA | Malaysian Investment Development Authority |
| MITI | Ministry of Investment, Trade and Industry |
| NCER | Northern Corridor Economic Region |
| HRD Corp | Human Resource Development Corporation |
| FMM | Federation of Malaysian Manufacturers |
| IoT | Internet of Things |
| AI | Artificial Intelligence |
| FIFO | First-In-First-Out |
| LIFO | Last In First Out |
| ASRS | Automated Storage and Retrieval Systems |
| AGV | Automated Guided Vehicle |
| TOE | Technology-Organization-Environment |
| RBV | Resource-Based View |
| SOP | Standard Operating Procedure |
| IT | Information Technology |
| HR | Human Resource |
| VRIN | Valuable, Rare, Inimitable, and Non-substitutable |

# CHAPTER ONE

# INTRODUCTION

## 1.0 Introduction

This chapter focusing study on warehouse operation accuracy and to overcome the issue in manufacturing warehouses in Kulim Hi-Tech Park. It covers the background of the study, identifies the research problem, and outlines the research questions and objectives. The chapter also defines the scope and significance of the study, provides definitions of key terms, and explains the organization of the study.

## 1.1 Background of the Study

Warehouse operation accuracy is a foundational element of successful warehouse and supply chain operations across the globe. In the era of Industry 4.0, the demand for real-time inventory visibility, operational efficiency, and customer responsiveness has pushed companies to adopt advanced technologies in warehousing systems. Globally, warehouse operation inaccuracies account for significant financial losses, with studies reporting that up to 30% of inventory records in some manufacturing warehouses are unreliable (Zhang et al., 2023). These inaccuracies lead to stockouts, overstocking and production delays, undermining operational performance and customer satisfaction.

To address these challenges, companies around the world have increasingly integrated technology system such as Enterprise Resource Planning (ERP), Warehouse Management Systems (WMS), and Radio Frequency Identification (RFID) technologies. According to Khan and Rasheed (2022), global adoption of RFID systems has increased by 18% between 2020 and 2022, particularly in sectors that depend on precise inventory control, such as electronic pharmaceuticals, and automotive manufacturing. In addition to technological solutions, storage design optimization and efficient material handling are also critical in reducing inventory discrepancies (Lim & Shafie, 2024).

In the Asian context, manufacturing remains a key economic driver, with countries like China, South Korea, Japan, Vietnam, and Malaysia playing central roles in global supply chains. As a result, Asia is witnessing accelerated adoption of smart warehousing solutions to mitigate issues related to inventory management. For example, countries like China and Singapore have invested heavily in warehouse automation and AI-powered inventory tracking. However, several ASEAN countries, including Malaysia, continue to face challenges due to fragmented systems, legacy infrastructure, and lack of integration across warehousing operations (Rahman et al., 2022).

In Malaysia, the manufacturing sector is a vital contributor to the nation's Gross Domestic Product (GDP), supported by key industrial zones such as the Kulim Hi-Tech Park in Kedah. This zone is home to high-precision industries including electronics and semiconductor manufacturing, where inventory accuracy is essential for maintaining lean production schedules and ensuring product traceability. Despite the adoption of ERP and WMS systems, many Malaysian manufacturers still experience inventory issues due to limitations in system integration, inefficient storage design, and inconsistent material handling practices (Noor & Hamzah, 2023).



Given the strategic importance of the manufacturing sector and the critical role played by industrial zone like Kulim Hi-Tech Park, addressing warehouse operation inaccuracies has become imperative. This research investigates the role of technology system, storage design, and material handling in mitigating inventory discrepancies in manufacturing warehousing. The study focuses on the context of Kulim Hi-Tech Park and aims to offer evidence-based recommendations that are both locally relevant and globally informed.

## 1.2 Problem Statement

Inventory accuracy is a critical determinant of operational efficiency, cost control, and customer satisfaction in manufacturing supply chains. Despite the availability of advanced technologies such as WMS, RFID, and barcode systems designed to provide real-time visibility and streamline warehouse operations many manufacturing firms continue to suffer from warehouse operation inaccuracies. These inaccuracies manifest as stockouts, overstocking, misplacements, and discrepancies between recorded and actual stock levels, all of which disrupt production schedules, reduce order fulfilment rates, and inflate operational costs (Budiyanto & Muslim, 2024; Fernandez-Carames et al., 2024).

Globally, the average inventory accuracy remains below 75%, with inventory distortions costing manufacturers over USD 1.1 trillion annually (Gitnux, 2025; MeteorSpace, 2025). While automated systems have demonstrated the potential to raise inventory accuracy to over 99%, studies reveal that many firms underutilize or poorly integrate these tools into daily operations (Soesanto et al., 2024). In many cases, outdated practices such as manual data entry, isolated systems, and fragmented handling processes persist, undermining the effectiveness of modern inventory control technologies.

One of the major contributors to these challenges is the suboptimal implementation or absence of robust technology system, such as barcode systems, WMS and RFID. These technologies are designed to streamline real-time data capture, improve traceability, and reduce manual entry errors. RFID technology offers real-time tracking and significantly improves inventory accuracy, organizational, technical, and economic barriers often prevent full implementation. Common challenges include resistance to change, interoperability issues, and high upfront costs leading many firms to adopt only partial or sub-optimal integration (Budiyanto & Muslim, 2024). Ultra-High Frequency Radio Frequency Identification (UHF RFID) integrated with IoT-enabled warehouse systems led to measurable gains in inventory accuracy. However, it also documents cases where lack of data linkage and poor system integration limited impact during periods of high transaction volumes (Soesanto et al. 2024). Inventory accuracy gains are constrained when the technologies are fragmented or not fully embedded within warehouse operations. The real-world experiments showed that seamless data flow is essential to achieving superior accuracy (Fernandez-Carames et al. 2024).

In addition to technological gaps, storage design deficiencies, such as poor layout planning, inadequate slotting strategies, and improper utilization of vertical space, further exacerbate warehouse operation inaccuracies. Studies have shown that inefficient storage arrangements can lead to misplaced items, difficulty in item retrieval, and increased cycle time (Chong & Yusof, 2023). This problem is particularly prevalent in high-volume, fast-paced manufacturing environments like those in Kulim Hi-Tech Park, where precise material flow and rapid order fulfilment are critical.

Moreover, existing research often treats technology system, storage design, and material handling as isolated factors, lacking an integrated analysis of how these elements collectively influence inventory accuracy particularly within the specific operational dynamics of Southeast Asian manufacturing zones. There is also a notable absence of localized studies that reflect the unique constraints, workforce dynamics, and system maturity levels found in Malaysian manufacturing facilities.

Therefore, a critical research gap exists in understanding the interrelationship between technology system, storage design, and material handling practices and how their combined implementation impacts inventory accuracy in manufacturing warehouses within Kulim Hi-Tech Park. Addressing this gap is essential not only for advancing academic understanding but also for offering practical, context-specific strategies to help firms reduce inventory discrepancies and enhance overall supply chain performance.

Table 1.1
*Current Statistics on Technology System, Storage Design, Material Handling, and Warehouse Operation Accuracy*

| Variable | Type | Indicator | Statistic (%) | Description | Source |
|---|---|---|---|---|---|
| Independent Variable | Material Handling | Warehouses with AS/RS systems | 55% (US) | Adoption rate for automated storage & retrieval systems | Gitnux (2025) (Gitnux) |
| Independent Variable | Material Handling | Robotics reducing labor costs in material handling | 20–30% reduction | Highlights cost-saving potential from robotic automation | WifiTalents (2025) (WifiTalents) |
| Independent Variable | Material Handling | Reliance on Manual Processes | 46% of SMBs still use manual inventory tracking; labor costs ~30% higher; picking error rate 23% | Manual methods drive inefficiency, high error rates, and elevated costs | LogixGrid, 2025 (LogixGRID) |
| Independent Variable | Storage Design | Unused Warehouse Space | 40% | Portion of warehouse space not utilized due to poor layout | Gitnux (2025a) |
| Independent Variable | Storage Design | Vertical Space Not Utilized | 60% | Warehouses failing to optimize vertical racking or stacking systems | Gitnux (2025a) |
| Independent Variable | Storage Design | Time Spent Searching for Misplaced Items | 10–20% | Time spent by employees locating items due to disorganized layout | Glocate (2025) |
| Independent Variable | Technology System | Productivity rise with automation | ~20% increase | Shows efficiency gains from automated systems | Gitnux (2025) (Gitnux) |
| Independent Variable | Technology System | Warehouses adopting digital transformation strategies | 72% | Emphasizes digitalization in material handling | WifiTalents (2025) (WifiTalents) |
| Independent Variable | Technology System | Reduction in warehouse operation inaccuracies via digital tools | 42% decrease | Demonstrates impact of digital implementation on inventory accuracy | WifiTalents (2025) (WifiTalents) |
| Dependent Variable | Warehouse Operation Accuracy | Inventory Accuracy Rate | 63% | Average accuracy rate in inventory records | Gitnux (2025b) |

Table 1.1 (Continued)

| | | | | | |
|---|---|---|---|---|---|
| Dependent Variable | Warehouse Operation Accuracy | Revenue Lost Due to warehouse operation Inaccuracies | 3–10% | Annual sales losses attributed to stockouts and incorrect inventory data | Gitnux (2025b) |
| Dependent Variable | Warehouse Operation Accuracy | Inventory Accuracy | Most facilities achieve only 85–90% accuracy, leading to shrinkage costing ~1.4% of revenue | Even small errors cause substantial financial impact due to phantom stock and inaccuracies | GoRamp, 2025 (GoRamp) |

Warehouse operational accuracy remains a pivotal metric in assessing supply chain efficiency, particularly in the manufacturing sector. In 2025, studies reveal that inventory accuracy rates average around 63%, with most facilities achieving between 85–90%, yet still facing shrinkage losses estimated at 1.4% of total revenue (Gitnux, 2025b; GoRamp, 2025). These discrepancies often lead to 3–10% of annual sales losses, primarily due to stockouts and incorrect inventory data.

One of the critical contributors to these inaccuracies is material handling practices. The adoption of Automated Storage and Retrieval Systems (AS/RS) has reached 55% in the U.S., highlighting the growing reliance on automation to boost efficiency (Gitnux, 2025). Similarly, robotic systems are credited with 20–30% reductions in labor costs, proving their value in high-volume operations (WifiTalents, 2025). Despite these advancements, a significant portion of small and medium-sized businesses (SMBs) 46% continue to rely on manual inventory tracking. This results in 30% higher labor costs and a picking error rate of 23%, further undermining warehouse accuracy (LogixGrid, 2025).

Equally important is storage design, which often remains under-optimized. Approximately 40% of warehouse space remains unused due to inefficient layout planning, and 60% of facilities fail to utilize vertical racking systems, thereby limiting their storage potential (Gitnux, 2025a). Poor slotting and layout designs also contribute to increased search times, with employees reportedly spending 10–20% of their time locating misplaced items (Glocate, 2025).

The integration of advanced technology systems continues to transform warehouse operations. Digital transformation strategies have been adopted by 72% of warehouses, resulting in a 42% reduction in warehouse operation inaccuracies and a 20% increase in productivity (WifiTalents, 2025; Gitnux, 2025). These technological investments underscore the importance of system applications in driving operational accuracy and efficiency.

In conclusion, achieving optimal warehouse accuracy in 2025 hinges on the integrated enhancement of material handling automation, strategic storage design, and robust technological infrastructure. Companies aiming to reduce losses and improve operational performance must prioritize these areas to stay competitive in the modern supply chain landscape.



### 1.3 Research Questions

1. How does analysing technology system such as RFID and WMS contribute towards warehouse operation accuracy in manufacturing companies?
2. How does analysing storage design contribute towards warehouse operation accuracy in manufacturing companies?
3. How does analysing material handling contribute towards warehouse operation accuracy in manufacturing companies?
4. Which practice demonstrates the most significant contribution towards warehouse operation accuracy in manufacturing companies?

### 1.4 Research Objectives

The study's research objectives are directly aligned with the research questions to ensure that the paper fulfils its research goals and objectives.

Specifically, the following research objectives have been identified:

1. To analyse the influence of technology system such as RFID and WMS towards warehouse operation accuracy in manufacturing companies.

2. To analyse the influence of storage design towards warehouse operation accuracy in manufacturing companies.

3. To analyse the influence of material handling towards warehouse operation accuracy in manufacturing companies.

4. To analyse the inventory management practice that demonstrates the most significant influence towards warehouse operation accuracy in manufacturing companies.

### 1.5 Scope of the Study



This study focuses on selected manufacturing warehouses in Kulim Hi-Tech Park, with an emphasis on facilities that have adopted system-based inventory management tools such as ERP and WMS. The analysis includes operational processes related to inventory control, storage design, and material handling within warehouse environments. The target population of this study consist of warehouse personnel, inventory managers, operations supervisors, and logistics professionals working in manufacturing companies located within Kulim Hi-Tech Park, particularly those directly involved in warehouse operations, inventory control, and material handling processes. This includes staff who are responsible for managing or overseeing inventory accuracy and tracking systems, such as WMS.

Kulim Hi-Tech Park is home to numerous multinational and local manufacturing firms specializing in electronics, semiconductors, and precision engineering industries where inventory accuracy is critical due to the high value, fast movement, and sensitivity of materials handled (Zulkifli et al., 2025). Employees in these roles possess firsthand knowledge and experience with the independent variables under study technology system, storage design, and material handling and are thus well-positioned to provide relevant, reliable data on their influence on the dependent variable, warehouse operation accuracy.

This scope ensures that the study captures real-world operational insights from practitioners who encounter inventory management challenges daily, thus enhancing the validity, relevance, and applicability of the research findings.

**1.6 Significance of the Study**

This study holds substantial significance from theoretical, practical, and policy-making perspectives, particularly within the context of manufacturing warehousing in Malaysia's industrial regions such as Kulim Hi-Tech Park.



From an academic standpoint, this study enriches the existing body of knowledge by integrating three critical dimensions, technology system, storage design, and material handling to assess their combined influence on warehouse operation accuracy. While previous research has often explored these factors in isolation (Ho et al., 2022; Chong & Yusof, 2023), limited empirical studies examine their interrelated effects within high-tech manufacturing environments. By addressing this research gap, the study contributes to warehouse operations and logistics management literature, particularly in developing economies where digital transformation in supply chain practices is still emerging (Zulkifli et al., 2025).

For practitioners, especially warehouse managers, logistics officers, and manufacturing operations supervisors, the findings will offer data-driven insights into how improvements in technology adoption, storage configuration, and handling practices can minimize warehouse operation inaccuracies. This is especially relevant for firms operating in Kulim Hi-Tech Park, where production efficiency and Just-in-Time (JIT) practices are paramount. The study aims to provide actionable recommendations that help organizations reduce discrepancies, optimize space, improve throughput, and enhance overall warehouse productivity.

This research also highlights the growing importance of technological integration, such as RFID, barcode systems, and WMS, in achieving real-time visibility and traceability. It demonstrates how technology must be complemented by effective physical layout design and standardized material handling practices to realize its full potential. These findings will be useful for Information Technology (IT) consultants and warehouse system vendors, enabling them to tailor solutions to the specific operational challenges faced by manufacturing firms.



On a broader scale, the study offers valuable insights to government agencies, policymakers, and industrial development bodies such as the Malaysian Investment Development Authority (MIDA) and Kulim Hi-Tech Park authorities. Understanding the infrastructural and operational limitations contributing to warehouse operation accuracy can help in shaping policy incentives, training programs, and investment strategies that promote smart warehousing and Industry 4.0 adoption among Malaysian manufacturers.

Finally, this research provides a conceptual framework and empirical evidence that can serve as a foundation for future academic inquiries. Researchers focusing on warehouse optimization, smart manufacturing, or supply chain resilience can build upon this study's findings to further explore causal relationships, conduct cross-industry comparisons, and apply advanced analytics and simulation models.

## 1.7 Definition of Key Terms

**Warehouse Operation Accuracy**: Degree to which warehouse activities, including receiving, put-away, picking, packing, and shipping are performed correctly, aligning with expected specifications (e.g., correct items, quantities, and conditions) and recorded accurately in system data (Hassan et al., 2023).

**Technology System**: Digital platforms such as ERP, WMS, and RFID that are used to track and manage inventory transactions in real-time. These applications help improve traceability and reduce manual errors (Alam et al., 2023; Komathi, 2024).

**Storage Design**: Refers to the spatial layout and organization of storage systems in a warehouse, including slotting, bin labeling, and zoning strategies, which directly affect picking efficiency and stock visibility (Teh & Latif, 2024; Zulkifli et al., 2025).

**Material Handling**: The tools and procedures involved in moving and storing inventory, such as forklifts, Automated Guided Vehicle (AGV), conveyors, and manual handling. Effective techniques minimize item misplacement and improve stock accuracy (Chong & Abdul Majid, 2025; Ismail et al., 2023).

**Kulim Hi-Tech Park**: A strategically developed industrial park in Malaysia, hosting advanced manufacturing facilities particularly in semiconductors, electronics, and high-precision industries, where inventory accuracy is vital for lean operations and global supply chain integration (Komathi, 2024; Zulkifli et al., 2025).

## 1.8 Organization of the Study

This research organized into five chapters, each structured to align with established academic conventions in postgraduate research and to ensure a logical flow of information. According to recent studies in logistics and operations management, structured chapter development enhances coherence and reader comprehension in empirical research (Noor & Hamzah, 2023; Tan & Ibrahim, 2022).

Chapter One introduces the research topic by presenting the background, problem statement, research questions and objectives, significance of the study, scope, definitions of key terms, and an overview of the study structure. These elements provide a foundation for understanding the rationale and direction of the research.

Chapter Two critically reviews previous studies related to inventory accuracy, technology applications, storage system design, and material handling. The chapter also establishes the theoretical framework and identifies research gaps, as suggested by Lim and Shafie (2024) in their call for context-specific warehouse research in Malaysia.

Chapter Three outlines the research design, population, sampling techniques, data collection methods, research instruments, and data analysis procedures. Ensuring methodological clarity and reliability is crucial for valid research outcomes (Rahman et al., 2022).



Chapter Four presents the analysed data and discusses the results in relation to the research objectives. Interpretation of the findings are aligned with existing literature and theoretical foundations (Zhang et al., 2023).

Chapter Five summarizes the main findings, highlights theoretical and practical contributions, outlines research limitations, and provides recommendations for future studies. This structure reflects best practices in postgraduate research reporting (Noor & Hamzah, 2023).

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This chapter critically examines the existing literature related to warehouse operation accuracy in manufacturing companies, with a particular emphasis on three interrelated constructs, technology system, storage design, and material handling. The primary aim is to establish a theoretical foundation for understanding how these factors collectively influence warehouse operation accuracy. Specifically, the chapter examines the situation within the context of manufacturing facilities at Kulim Hi-Tech Park, Malaysia, where operational efficiency is essential for maintaining competitive advantage in the industry.

Despite significant advancements in technology and management practices, current literature reveals persistent warehouse operation inaccuracies across manufacturing warehouses globally, a problem that continues to undermine productivity and profitability. Recent studies (2022–2025) point to substantial improvements in automated systems such as Warehouse Management Systems (WMS), RFID, and barcode technology, yet discrepancies in warehouse operation remain widespread. The fact that many firms continue to struggle with manual processes and inadequate technological integration suggests that existing solutions are not fully effective or universally applicable. In particular, underutilization of available technologies, as well as challenges in adapting them to local contexts, exacerbates the problem.

Moreover, while storage design and material handling are often identified as critical factors in warehouse operation, the interplay between these elements and technological systems has received insufficient attention. Current literature tends to isolate these factors, neglecting how integrating technology with optimal storage layouts and standardized handling procedures could offer a more comprehensive solution to operation challenges.

Furthermore, there is a notable absence of research focusing on the specific needs of high-tech industrial zones like Kulim Hi-Tech Park, where fast-paced production schedules demand precise coordination of these factors.

This review also highlights persistent gaps in the literature. Despite numerous studies examining the individual constructs, there is a clear lack of integrated models that address the combined impact of system applications, storage design, and material handling on warehouse operation accuracy. In addition, much of the research is either focused on developed economies or large-scale corporations, leaving smaller-scale manufacturing operations in regions like Southeast Asia underexplored.

In light of these issues, this review argues that the existing body of knowledge is insufficient to address the evolving challenges faced by manufacturers in high-tech zones. The synthesis of findings from recent studies (2022–2025) not only illuminates the ongoing inefficiencies but also underscores the need for more contextual research that can offer practical, integrated solutions. The gaps identified in this review provide the foundation for this study, which aims to bridge these gaps and contribute new insights to the field of operation management in manufacturing.

## 2.2 Empirical Review

### 2.2.1 Empirical Review of Warehouse Operation Accuracy

Warehouse operation accuracy is a critical component of warehouse performance and has direct implications for cost efficiency, customer satisfaction, and production planning (Osman et al., 2025). High inventory accuracy reduces order cycle time, minimizes carrying costs, and improves responsiveness to market demand.

Lim et al. (2024) reported that firms with inventory accuracy rates above 95% experienced significant improvements in on-time deliveries and customer satisfaction. In high-precision environments like Kulim Hi-Tech Park, where semiconductor and electronics industries dominate, inventory accuracy supports compliance with quality standards such as Quality Management System (ISO 9001) and Quality Management System Standard specifically for the automotive industry (IATF 16949).

Inventory accuracy yields multiple benefits across operational, strategic, and compliance dimensions. It enhances order fulfilment, reduces operational costs, improves forecasting, and ensures audit readiness. Real-time inventory systems have been empirically shown to reduce carrying costs by around 20%, while stockout-related costs can drop by up to 25% in retail environments (Poolakkal Mukkath, 2025). Firms that implement real-time analytics also report 15% fewer stockouts and 15–20% improved order fulfilment, underscoring improved delivery performance (MoldStud Research Team, 2025). Moreover, accurate demand forecasting supported by AI analytics can boost forecast accuracy by 20–50%, optimizing inventory decisions and enhancing production planning, ultimately leading to stronger customer satisfaction and lower operational inefficiencies (SuperAGI / McKinsey, 2025).



Warehouse operation inaccuracy in Kulim Hi-Tech Park is often linked to a combination of technological, design, and human factors. Komathi (2024) identified poor system integration and lack of SOPs as major issues. Ramli et al. (2023) highlighted human error and insufficient training, while Zulkifli et al. (2025) pointed to infrastructure limitations and disconnected systems.

Teh and Latif (2024) found that improper storage layout led to higher cycle count variances, and Chong and Abdul Majid (2025) noted that manual handling inconsistencies significantly affected inventory reliability. These empirical findings underscore the need for an integrated approach combining technology system, storage optimization, and efficient material handling.

### 2.2.2 Empirical Review of Technology System

Modern warehouse systems are increasingly adopting smart technologies such as IoT, AI, and cloud-based platforms to automate data collection, perform predictive analysis, and enable seamless communication between warehousing subsystems (Alam et al., 2023; Chen et al., 2022). These advancements allow for better forecasting, reduced stock discrepancies, and enhanced inventory turnover.

Recent empirical studies support the adoption of technology system as a core mechanism to reduce warehouse operation inaccuracies. Alam et al. (2023) demonstrated that the implementation of RFID in Malaysian manufacturing firms reduced inventory mismatches by 38% and improved stock traceability. Roslan et al. (2024) investigated WMS integration in Johor-based factories and found a direct connection between technology system usage and reduced stock discrepancies, noting improvements in cycle count accuracy and replenishment planning.

In another study, Lee and Harun (2022) examined the adoption of ERP systems in mid-sized manufacturers across Kedah and concluded that real-time inventory data and automated tracking significantly lowered shrinkage rates. Additionally, Ng and Karim (2025) highlighted that firms deploying AI-integrated WMS experienced a 45% boost in inventory location accuracy, indicating that technology-driven environments consistently outperform manual or hybrid systems.

### 2.2.3 Empirical Review of Storage Design

Storage design encompasses the structural and spatial configuration of a warehouse. It plays a vital role in facilitating efficient product handling, minimizing congestion, and improving access to inventory. Key design components include racking systems, aisle width, zoning, and slotting strategies. The design not only influence how items stored but also influences picking accuracy, travel time, and inventory visibility (Rahman et al., 2023).

Strategic storage configurations such as randomized storage with system support, First-In-First-Out (FIFO) layouts, and dynamic slotting help improve accessibility and reduce the likelihood of stockouts or overstocking. In high-tech manufacturing settings, automated solutions like Automated Storage and Retrieval Systems (ASRS) and vertical lift modules have been increasingly adopted to optimize space utilization and precision.

Empirical research continues to highlight the importance of storage design in enhancing warehouse performance. Rahman et al. (2023) studied storage layouts in industrial warehouses in Penang and found that optimized storage configuration reduced order picking errors by 27%. Zulkifli et al. (2022) conducted an analysis in central Malaysian warehouses and concluded that dedicated zoning reduced item misplacement, especially in high-turnover environments.



Teh and Latif (2024) explored the relationship between storage design and inventory visibility in manufacturing plants in Kulim Hi-Tech Park. Their findings suggested that warehouses employing modular storage systems and space-optimized racking reduced cycle counting time and increased inventory accuracy rates. Wong and Ibrahim (2025) found that integrating storage planning with WMS systems enhanced inventory control and significantly improved space-to-volume efficiency.

### 2.2.4 Empirical Review of Material Handling

The goal of effective material handling is to reduce product damage, minimize manual labour, and increase throughput. Integrating handling equipment with tracking technologies like RFID or barcode systems improves real-time inventory control and reduces losses due to misplacement or miscounting (Ismail et al., 2023). Furthermore, material handling decisions directly affect cycle times, productivity, and safety.

Recent studies affirm that advanced material handling lead to improved inventory accuracy and operational efficiency. Ismail et al. (2023) reported that manufacturers in Selangor utilizing AGV and semi-automated conveyors experienced a 42% improvement in material movement accuracy. Ghazali and Tan (2022) highlighted that structured manual handling protocols, when combined with ergonomic training, reduced human-induced inventory errors by up to 30%.

Nor and Yusof (2024) studied material handling in Johor's electronics manufacturing sector and revealed that standardized handling processes, integrated with WMS data inputs, significantly minimized misplaced items. Furthermore, Chong and Abdul Majid (2025) identified that firms deploying smart handling systems, including IoT-enabled trolleys and real-time scanners, reported improved picking speeds and inventory reconciliation accuracy.

### 2.2.5 Empirical Review of Technology System, Storage Design and Material Handling

Table 2.1
*Empirical Review Table*

| Author's name | Research Title | Findings |
|---|---|---|
| Al-Hawary et al. (2023) | Warehouse technology and inventory performance: Evidence from SMEs | Adoption of WMS and RFID led to a 42% improvement in inventory visibility and 33% reduction in stock errors. |
| Hassan et al. (2022) | RFID implementation in Malaysian manufacturing | RFID-enabled warehouses experienced a 38% reduction in manual entry errors and a 25% increase in stock accuracy. |
| Huang & Liu (2022) | Lean warehousing and operational accuracy | Lean-based storage practices reduced inventory discrepancies by 29% and improved cycle counting accuracy by 31%. |
| Kumar et al. (2024) | Digital transformation in warehouse operations | ERP and IoT tools improved inventory tracking by 45% and reduced shrinkage incidents by 34%. |

Table 2.1 (Continued)

| Author's name | Research Title | Findings |
|---|---|---|
| Lee et al. (2023) | Impact of warehouse layout on inventory control | Optimized racking and zoning increased order picking accuracy by 36% and stock accessibility by 40%. |
| Pereira et al. (2022) | Measuring inventory performance through digital tools | Use of barcode and RFID improved stock variance metrics by 31% and reduced misplacements by 27%. |
| Rathnayaka et al. (2023) | Sampling frameworks in logistics research | Stratified sampling improved response relevance and coverage by 28% across logistics sectors. |
| Singh & Sharma (2023) | Material handling strategies and operational efficiency | Automated material handling reduced picking errors by 41% and improved throughput by 35%. |



## 2.3 Theoretical Review

Theoretical frameworks offer a structured lens through which to understand the complexities of warehouse operations. This study employs three primary theories to contextualize the challenges in technology system, storage design, and material handling. They are Technology-Organization-Environment (TOE) Framework, Resource-Based View (RBV), and Lean Warehousing Theory.

### 2.3.1 Technology-Organization-Environment (TOE) Framework

Developed by Tornatzky and Fleischer (1990), the TOE framework explains how technological, organizational, and environmental contexts influence a firm’s decision to adopt and implement recent technologies. This framework is particularly relevant in examining the adoption of integrated WMS and automation tools.

Technological context refers to the availability, complexity, and compatibility of new systems such as WMS, RFID, or AS/RS (Fakhrai Rad et al., 2025). Warehouses often face difficulties integrating these technologies due to legacy systems and excessive costs.

Organizational context includes firm size, management support, and human resources. Resistance to change and lack of skilled labour are usual challenges in implementing new picking or storage technologies (Omniful, 2025).

Environmental context encompasses industry competition, regulatory pressure, and customer expectations. Increasing cybersecurity threats and e-commerce growth drive the need for integrated and responsive warehousing systems (Y3.sg, 2025). The TOE framework helps explain why some warehouses lag in technology adoption while others lead in innovation.

### 2.3.2 Resource-Based View Theory (RBV)

RBV, introduced by Barney (1991), argues that firms can achieve and sustain a competitive advantage by strategically utilizing resources that are valuable, rare, inimitable, and non-substitutable. In the context of warehousing, this theory helps explain how certain internal capabilities and assets contribute to superior operational outcomes, such as improved inventory accuracy and warehousing efficiency.

Physical resources in this setting include infrastructure such as storage systems and automation technologies like conveyors and robotics, which enable faster and more accurate handling of inventory. Human resources refer to a workforce that is not only skilled but also adaptable in managing technologically advanced warehouse environments, where real-time decision-making and system integration are critical. Furthermore, organizational capabilities such as the ability to implement integrated WMS, design intelligent layout configurations, and optimize material flow, also play a pivotal role.

RBV is particularly valuable for explaining how the deployment of advanced warehouse configurations, such as (AS/RS), and the use of superior picking methods, can become sources of sustained operational advantage. As noted by Xu, Zhang, and Huang (2022), warehouses that invest strategically in intelligent layout design, efficient picking strategies, and secure IT infrastructure are better positioned to outperform competitors over time. These resources, when aligned with organizational strategy, enable firms to mitigate warehouse operation inaccuracies and build long-term competitive capabilities.

### 2.3.3 Lean Warehousing Theory

Lean theory, which was originally developed within the manufacturing sector, has since been effectively adapted for warehouse operations with the aim of minimizing waste and maximizing customer value. Lean warehousing focuses on the systematic elimination of non-value-adding activities such as excessive movement, overstocking, waiting time, and inefficiencies in the picking process (Alicke et al., 2022).



Central to lean warehousing is the implementation of standardized processes that promote accuracy and consistency in storage and retrieval activities. These processes help reduce errors and ensure smooth material flow throughout the warehouse. The principle of continuous improvement, commonly referred to as *Kaizen*, encourages organizations to regularly evaluate and refine their operations to enhance efficiency and reduce waste. Another key element is the JIT approach, which seeks to align inventory levels with actual customer demand, thereby minimizing the costs associated with holding excess stock.

Lean principles also support the adoption of more efficient picking strategies, such as zone picking or batch picking, which are designed to streamline operations and reduce redundant movements. Additionally, lean warehousing emphasizes the importance of a well-organized and clutter-free storage layout to minimize travel distances, reduce congestion, and enhance productivity (Hopstack, 2025). By applying these principles, organizations can achieve more accurate inventory levels and create a more agile and responsive warehousing environment.

## 2.4 Proposed Hypothesis

### a. Technology System Influence on Warehouse Operation Accuracy

Technology system such as WMS, ERP, Barcode Systems, and RFID plays a pivotal role in reducing warehouse operation inaccuracies by automating data entry, enhancing real-time visibility, and minimizing human error. Manual recording of stock movements often leads to data entry errors, misplaced items, and inaccurate stock counts. Technology system digitize these processes.

Hassan et al. (2022) found that RFID implementation reduced manual entry errors by 38%, improving overall stock accuracy by 25%. Technologies like WMS and RFID enable real-time updates on stock levels, movement history, and location within the warehouse. Al-Hawary et al. (2023) observed a 42% increase in inventory visibility through WMS and RFID, which significantly decreased stock discrepancies.



ERP systems help in synchronizing inventory data across departments, reducing mismatches between physical stock and recorded stock. Kumar et al. (2024) highlighted that digital tools, including ERP, reduced shrinkage by 34% and improved stock record accuracy by 45%. WMS and ERP systems can generate alerts for low stock, overstock, or mismatches, thus proactively addressing potential inaccuracies.

Lee et al. (2023) showed that automated stock control features improved picking accuracy by 36% and reduced stockouts by 28%. Barcode and RFID systems enhance traceability of stock movement and facilitate faster audits. Pereira et al. (2022) reported a 31% improvement in stock variance tracking due to system-based item-level identification.

Based on the above discussion, the following hypothesis were formulated.

*H1: There is a positive and significant relationship between the use of technology system and warehouse operation accuracy in manufacturing warehousing by automated data entry.*

**b. Storage Design Influence on Warehouse Operation Accuracy**

Storage design refers to how inventory is physically organized, structured, and accessed within a warehouse. Elements include racking systems, zoning, labelling, bin locations, and layout optimization. Poor storage design contributes to misplacements, picking errors, and inventory mismatches making it a critical factor in reducing inaccuracies. Efficient layouts ensure faster and more accurate item retrieval. Poorly planned storage leads to stock being placed in incorrect or hard-to-locate areas.

Lee et al. (2023) reported a 36% increase in picking accuracy and 40% improvement in stock accessibility when warehouses implemented optimized storage zoning and racking. Dividing storage into zones by item type, usage frequency, or hazard class helps prevent cross-storage and misplacement. Huang & Liu (2022) found that clear zoning practices reduced inventory discrepancies by 29% and improved cycle count accuracy by 31%. Strategic labelling and clearly marked bin locations reduce ambiguity during stock put-away or retrieval.

Pereira et al. (2022) noted that improved bin labelling and digital mapping reduced misplacement incidents by 27%. Proper storage structures that support FIFO or LIFO (Last-In, First-Out) principles reduce expired/obsolete stock, avoiding false discrepancies. Kumar et al. (2024) observed a 34% improvement in inventory rotation accuracy with racking systems that enforced FIFO practices. Utilizing vertical space with high-density racking prevents item stacking on floor areas, which often leads to errors in manual stock handling. Al-Hawary et al. (2023) indicated that vertical storage led to a 33% reduction in misplaced items and stock loss.

Based on the above discussion, the following hypothesis were formulated.

*H2: There is a positive and significant relationship between effective storage design and warehouse operation accuracy in manufacturing warehousing by minimizing misplaced items.*

**c. Material Handling Influence on Warehouse Operation Accuracy**

Material handling refers to the movement, protection, storage, and control of materials within a warehouse using equipment, labor, and automation. Inappropriate or inefficient material handling leads to misplaced items, damages, incorrect deliveries, and inaccurate inventory records. Proper handling techniques are essential for reducing such discrepancies and maintaining inventory integrity.

Automation such as conveyors, (AGVs), and robotic arms reduce dependence on manual handling, which is prone to human error. Singh & Sharma (2023) found that automation reduced picking and placement errors by 41% and increased throughput by 35%. Having clear procedures for receiving, put-away, picking, and dispatch reduces variability in handling.

Kumar et al. (2024) reported that implementing Standard Operating Procedures (SOPs) led to a 28% reduction in incorrect stock movements. Choosing suitable equipment (e.g., pallet jacks vs. forklifts) based on product weight and fragility reduces damage-related write-offs. Lee et al. (2023) highlighted that matching equipment to load type decreased inventory loss due to damage by 22%. Trained personnel are less likely to misplace, damage, or wrongly record items during handling.

Hassan et al. (2022) demonstrated that operator training programs improved handling accuracy by 26% and lowered misplacement incidents. Linking material handling systems with WMS or ERP allows real-time tracking and automatic data updates during item movement. Pereira et al. (2022) noted a 30% improvement in inventory traceability when handling systems were integrated with tracking technologies.

Based on the above discussion, the following hypothesis were formulated.

*H3: There is a positive and significant relationship between efficient material handling and warehouse operation accuracy in manufacturing warehousing by minimizing errors in material movement.*

**2.5 Research Framework**

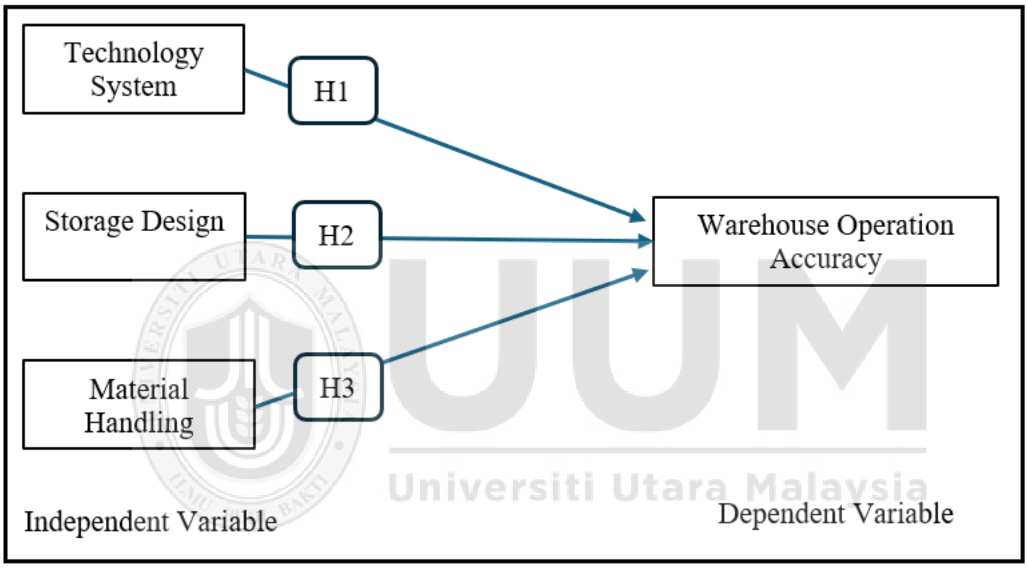


Figure 2.1
*Research Framework*
Source: Researcher's Own Construct, 2025

The research framework developed in this study illustrates a direct and structured relationship between three key independent variables, technology system, storage design, and material handling and the dependent variable, inventory accuracy, within the context of manufacturing warehousing. The framework posits that the implementation of advanced technology systems, such as Warehouse Management Systems (WMS), Radio Frequency Identification (RFID), and barcode applications, enhances inventory tracking, minimizes manual errors, and supports real-time stock visibility, thereby contributing to higher levels of warehouse operation accuracy. In parallel, an efficiently planned storage design incorporating optimized layouts, vertical racking, logical slotting, and clearly labelled zones ensures easier access, faster retrieval, and reduced stock misplacement, all of which are essential for maintaining accurate inventory records. Additionally, the role of material handling, including the use of automation (e.g., conveyors and scanners), standardized operating procedures (SOPs), and trained personnel, supports the accurate movement, placement, and documentation of stock items. These three components collectively form a comprehensive operational system that reduces errors, improves stock reliability, and enhances inventory precision. As proposed in the framework, the integration of these practices strengthens warehouse performance and directly leads to improved inventory accuracy, which is critical for production planning, order fulfilment, and supply chain efficiency in high-tech manufacturing environments like Kulim Hi-Tech Park.

## 2.6 Summary

This chapter has reviewed the current literature on warehouse operations, highlighting the complexities and challenges associated with technology system, storage design, and material handling. Studies from 2022 to 2025 confirm that inventory accuracy is a multifaceted issue influenced by technological capabilities, warehouse infrastructure, and human practices.

The synthesis of recent studies underscores the need for integrated approaches to enhance warehouse efficiency. In Kulim Hi-Tech Park, the integration of these elements is critical for achieving operational excellence. The identified research gaps justify the necessity for this study, which seeks to provide comprehensive insights and practical solutions to optimize warehouse operations in Kulim Hi-Tech Park.

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter outlines the methodology adopted to investigate technology system, storage design, and material handling influence inventory accuracy in manufacturing warehousing at Kulim Hi-Tech Park. The design ensures systematic data collection, validity, and analysis, contributing to the reliability and relevance of the findings. Recent studies (Ali & Saleh, 2022; Tan et al., 2024; Fazli et al., 2025) have emphasized the importance of robust methodological frameworks when evaluating technological influence in logistics.

Table 3.1
*Dependent Variable & Independent Variables vs Theory*



| Variable | Type | Relevant Theory | Justification | Recent Citation (2022–2025) |
|---|---|---|---|---|
| Warehouse Operation Accuracy | Dependent Variable (DV) | Resource-Based View (RBV) | Viewed as a strategic resource that provides a competitive advantage by improving customer satisfaction and reducing costs. | Fazli et al. (2025); Kim & Lee (2023) |
| Technology System | Independent Variable (IV) | Technology-Organization-Environment (TOE) Framework | Technology adoption (e.g., WMS, RFID) improves data visibility and process automation, which enhances inventory accuracy when aligned with organizational readiness. | Tan et al. (2024); Osman & Rahim (2022) |

Table 3.1 (Continued)

| Variable | Type | Relevant Theory | Justification | Recent Citation (2022–2025) |
|---|---|---|---|---|
| Storage Design | Independent Variable (IV) | Lean Warehousing Theory | Lean principles emphasize structured storage to reduce waste, speed up retrieval, and improve inventory control accuracy. | Abdullah et al. (2022); Noor & Hassan (2023) |
| Material Handling | Independent Variable (IV) | Resource-Based View (RBV) | Efficient handling practices and equipment are considered valuable operational resources that help reduce inventory errors and improve stock reliability. | Lee et al. (2023); Manimaran & Ramesh (2024) |



**3.2 Research Design**

The study adopts a quantitative research design, which is particularly appropriate for assessing the influence of multiple independent variables on a dependent variable across a sample population. This design enables objective measurement and statistical testing of hypothesis. Quantitative research is ideal for this study as it helps in understanding the relationships between technology adoption, storage design efficiency, and material handling effectiveness with inventory accuracy (Al-Hawary et al., 2023).

A cross-sectional survey design is utilized, where data are collected at a single point in time from a sample of manufacturing firms. This approach is cost-effective and suitable for identifying current patterns and practices without the need for long-term tracking.

The study is both descriptive and explanatory in nature. The descriptive component focuses on identifying and detailing the current inventory practices and technologies in use within Kulim Hi-Tech Park. The explanatory component goes further to examine the causal relationships among technology system, storage design, and material handling in relation to inventory accuracy (Kumar et al., 2024).

A structured questionnaire enables the collection of quantitative data, which is suitable for statistical analysis and hypothesis testing. Structured questionnaires are ideal for studies aiming to collect standardized and comparable data across a large sample (Saunders et al. 2023). A structured questionnaire ensures all respondents are asked the same questions in the same order, increasing reliability, consistency, and objectivity of responses across the sample. Structured formats reduce interviewer bias and maintain measurement uniformity (Sekaran & Bougie 2022).

### 3.3 Research Population, Sample, and Unit of Analysis

#### 3.3.1 Research Population

The research population refers to the entire group of individuals or elements that possess the characteristics of interest to the study (Sekaran & Bougie, 2022). In this study, the research population comprises warehouse personnel working in manufacturing companies located within Kulim Hi-Tech Park. This includes individuals who are directly involved in warehousing operations and inventory control, such as warehouse managers, executives, supervisors, inventory controllers, material handlers, and WMS coordinators. These individuals are chosen because they are directly engaged in the day-to-day handling, storage, tracking, and recording of inventory items, which are central to the problem of warehouse operation inaccuracies. According to Mohd Yusof et al. (2023), involving personnel with operational experience in inventory management improves the reliability and relevance of the data collected in logistics and warehousing studies. Based on Kulim Hi-Tech Park Company Profile, there a total of 40 manufacturing companies operating as of 2024.

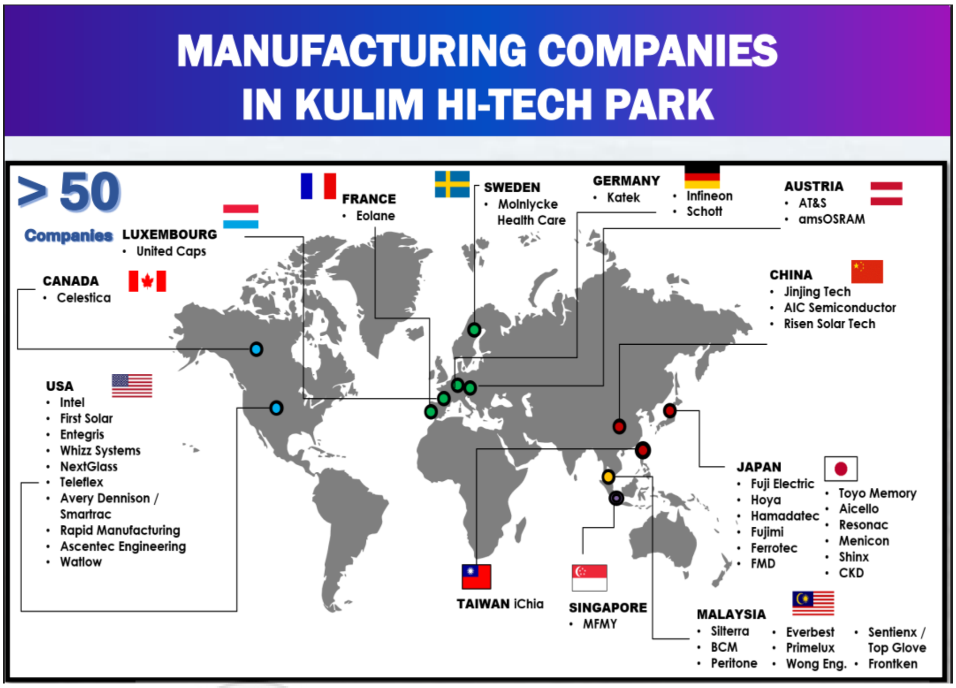


**Figure 3.1**
*List of Manufacturing Companies in Kulim Hi-Tech Park*
Source: Kulim Hi-Tech Company Profile 2024

### 3.3.2 Research Sample

This study targeted a total population of 40 manufacturing companies operating in Kulim Hi-Tech Park, each with relevant personnel involved in warehouse and inventory operations. Referring Table 3.1, Krejcie and Morgan's (1970) sample size determination table, the recommended sample size for a population of 40 is 36. The study obtained 30 complete and valid responses, achieving 83% of the target sample, which is considered reasonable and statistically usable, particularly in a purposive sampling framework. In business-to-business (B2B) or industrial settings, response rates and raw respondent counts are often lower than in general population surveys due to the specialized nature of roles and gatekeeping in corporate environments. Studies in manufacturing, logistics, and supply chain often report respondent numbers ranging from 20 to 50 as acceptable for targeted operational research (Malhotra & Dash, 2016; Sauro, 2022). Thus, a total of 30 respondents with direct operational experience provides a strong foundation for meaningful analysis.

The purposive sampling method employed ensured that only individuals with direct involvement in inventory management and warehouse operations were surveyed, such as warehouse supervisors, inventory controllers, and logistics officers. This increases the relevance and depth of the data, making each respondent's input more analytically valuable than in broader, less-focused sampling methods. Current research highlights that data quality depends more on the representativeness of the sample than the absolute number of responses. As long as the sample adequately reflects the key roles, departments, and company types within the target population, smaller sample sizes can still yield valid and actionable insights (Peytchev, 2023; Danish National Health Survey, 2023).

Table 3.2
*Sample Determination Table*

Table for Determining Sample Size from a Given Population

| N | S | N | S | N | S |
|---|---|---|---|---|---|
| 10 | 10 | 220 | 140 | 1200 | 291 |
| 15 | 14 | 230 | 144 | 1300 | 297 |
| 20 | 19 | 240 | 148 | 1400 | 302 |
| 25 | 24 | 250 | 152 | 1500 | 306 |
| 30 | 28 | 260 | 155 | 1600 | 310 |
| 35 | 32 | 270 | 159 | 1700 | 313 |
| 40 | 36 | 280 | 162 | 1800 | 317 |
| 45 | 40 | 290 | 165 | 1900 | 320 |
| 50 | 44 | 300 | 169 | 2000 | 322 |
| 55 | 48 | 320 | 175 | 2200 | 327 |
| 60 | 52 | 340 | 181 | 2400 | 331 |
| 65 | 56 | 360 | 186 | 2600 | 335 |
| 70 | 59 | 380 | 191 | 2800 | 338 |
| 75 | 63 | 400 | 196 | 3000 | 341 |
| 80 | 66 | 420 | 201 | 3500 | 346 |
| 85 | 70 | 440 | 205 | 4000 | 351 |
| 90 | 73 | 460 | 210 | 4500 | 354 |
| 95 | 76 | 480 | 214 | 5000 | 357 |
| 100 | 80 | 500 | 217 | 6000 | 361 |
| 110 | 86 | 550 | 226 | 7000 | 364 |
| 120 | 92 | 600 | 234 | 8000 | 367 |
| 130 | 97 | 650 | 242 | 9000 | 368 |

Krejcie and Morgan (1970) sample determination table. Source: Krejcie and Morgan (1970).

Source: Krejcie and Morgan (1970)

The combination of stratified and purposive sampling techniques was strategically employed in this study to enhance the representativeness and relevance of the data collected from manufacturing firms in Kulim Hi-Tech Park. Stratified sampling was used at the company level to ensure that manufacturing firms from different countries of origin (e.g., USA, Japan, Malaysia, Germany) were proportionally represented in the sample. This approach allowed for a more balanced and accurate reflection of the diverse industrial presence within the park.

According to Rathnayaka et al. (2023), stratified sampling improves coverage and reduces sampling error by ensuring that all significant subgroups are included in the analysis. This is especially important in heterogeneous environments like Kulim Hi-Tech Park, where warehouse practices may vary by country of ownership and operational maturity. Once the stratified company sample was determined, purposive sampling was applied to select individual respondents specifically warehouse managers, supervisors, and inventory staff with direct involvement in inventory control processes.

As noted by Etikan et al. (2022) and Tan et al. (2024), purposive sampling is suitable when the objective is to gather insights from individuals with specific knowledge and experience relevant to the research problem. This method ensured that responses came from qualified professionals capable of providing informed and contextually relevant input on technology system, storage design, and material handling. The combination of these two sampling techniques therefore enhanced both the external validity (through company stratification) and internal validity (through respondent selection) of the study, leading to more reliable and generalizable findings within the scope of manufacturing warehousing in Malaysia.

Table 3.3
*Proportional Stratified Sampling Method*

| Manufacturing Companies in Kulim Hi-Tech Park | Number of Companies | Sample Size (Proportional to 36) | Rounded Sample Size (Workforce) |
|---|---|---|---|
| Luxembourg | 1 | (1/40)*36=0.90 | 1 |
| Canada | 1 | (1/40)*36=0.90 | 1 |
| USA | 10 | (10/40)*36=9.0 | 9 |
| Philippines | 1 | (1/40)*36=0.90 | 1 |
| Singapore | 2 | (2/40)*36=1.8 | 2 |
| Malaysia | 7 | (7/40)*36=6.3 | 6 |
| Japan | 9 | (9/40)*36=8.1 | 8 |
| China | 2 | (2/40)*36=1.8 | 2 |
| Austria | 1 | (1/40)*36=0.90 | 1 |
| Germany | 4 | (4/40)*36=3.6 | 4 |
| Sweden | 1 | (1/40)*36=0.90 | 1 |
| **Total** | **40** | | **36** |

### 3.3.3 Unit of Analysis

The unit of analysis is the primary entity being studied in the research and to which the researcher intends to generalize the results (Sekaran & Bougie, 2022). For this study, the individual is selected as the unit of analysis. Specifically, the unit of analysis consists of individual employees who are directly involved in warehousing and inventory operations within manufacturing companies located in Kulim Hi-Tech Park. Since the structured questionnaire includes perceptual measures (e.g., perceived system effectiveness, frequency of inventory mismatch), individual responses provide critical insights into the practical implementation of systems and practices. According to Hair et al. (2022), when investigating attitudes, experiences, or perceptions in organizational settings, individuals are the most appropriate unit of analysis.

Collecting data from individuals, rather than organizational units or departments, enables quicker access to information, especially through structured questionnaires. This is particularly relevant in time-sensitive industrial environments such as manufacturing warehouses. Mohamad et al. (2024) emphasize that in Malaysian manufacturing logistics research, individual-based analysis yields better response rates and practical findings. Each objective and hypothesis of the study are structured around the experiences and practices of individual workers. Therefore, aligning the unit of analysis with the individual allows for valid, relevant, and analysable data consistent with the study's design.

### 3.4 Sampling Method

For this research, the non-probability purposive sampling method is employed. Purposive sampling is a type of non-probability sampling technique where respondents are deliberately selected based on specific characteristics relevant to the research problem (Etikan et al., 2022). This method is appropriate when the researcher needs to gather insights from knowledgeable and experienced individuals directly involved in the phenomena under study.

In this research, purposive sampling is chosen to ensure that only qualified respondents those directly involved in warehousing operations in Kulim Hi-Tech Park manufacturing companies are included. These respondents are more likely to provide meaningful, accurate, and experience-based responses.



### 3.5 Questionnaire Preparation

A structured questionnaire is adopted as the primary data collection instrument for this research. It is designed to obtain quantitative data from warehouse personnel regarding their perceptions and experiences with technology system, storage design, material handling, and warehouse operation accuracy. The questionnaire is constructed to ensure clarity, relevance, and alignment with the research objectives and hypothesis. According to Sekaran and Bougie (2022), a well-designed questionnaire enhances data reliability, improves response accuracy, and minimizes bias. The questionnaire are divided into 5 key sections, such as, demographic information, technology system, storage design, material handling and warehouse operation accuracy.

### 3.5.1 Measurement of Variables

This section outlines how each variable in the research framework is operationally defined and measured using structured questionnaire items. The measurement is based on validated indicators from prior studies and aligned with the study's hypothesis and objectives. All constructs are measured using multi-item Likert scales, typically on a

6-point scale ranging from, 1 = strongly disagree until 6 = strongly agree.

**a. Dependent variable – Warehouse Operation Accuracy (WOA)**

Table 3.4 measures the extent and frequency of mismatches between physical inventory and recorded inventory data.

Table 3.4
*Measurement for Warehouse Operation Accuracy (WOA) - (9 items)*

| Dimension | Items | Related Source |
|---|---|---|
| WOA1 | Inventory discrepancies between system records and actual stock are frequent in warehouse. | Adapted according to Lee et al. (2022) & Azman et al. (2022) |
| WOA2 | Inaccurate inventory records have caused delays in order fulfilment. | |
| WOA3 | Team often discovers unexpected stockouts during picking operations. | |
| WOA4 | Overstocking due to inaccurate forecasting or records is a common issue. | |
| WOA5 | Manual inventory updates increase the likelihood of human error. | |

Table 3.4 (Continued)

| Dimension | Items | Related Source |
|---|---|---|
| WOA6 | Periodic audits frequently reveal inconsistencies in stock levels. | Adapted according to Lee et al. (2022) & Azman et al. (2022) |
| WOA7 | Inventory errors often result in customer complaints or returns. | |
| WOA8 | Inaccurate inventory has disrupted production scheduling. | |
| WOA9 | Cycle counting is effective in identifying warehouse operation inaccuracies. | |

**b. Independent variable 1 - Technology System (TECH)**

Table 3.5 refers to the usage and effectiveness of digital systems such as WMS, RFID, and barcode scanning technologies in inventory management.

Table 3.5
*Measurement for Technology System (TECH) - (9 items)*

| Dimension | Items | Related Source |
|---|---|---|
| TECH1 | We utilize a Warehouse Management System (WMS) to manage inventory operations. | Adapted according to Mohamad et al. (2024) & Yusof et al. (2023) |
| TECH2 | WMS provides real-time tracking of inventory across storage zones. | |
| TECH3 | The use of barcode systems improves stock location accuracy. | |
| TECH4 | Integration between WMS and actual material enhances inventory visibility. | |
| TECH5 | Inventory discrepancies have reduced since adopting digital systems. | |

Table 3.5 (Continued)

| Dimension | Items | Related Source |
|---|---|---|
| TECH6 | Employees are trained yearly to use inventory software systems. | Adapted according to Mohamad et al. (2024) & Yusof et al. (2023) |
| TECH7 | Warehouse uses AI-driven analytics for inventory forecasting. | |
| TECH8 | System-generated alerts help identify potential inventory mismatches. | |
| TECH9 | Technology adoption has decreased reliance on manual stocktaking. | |

**c. Independent variable 2 – Storage Design (STORE)**

Table 3.6 refers to the physical design, layout, and organization of storage areas in a warehouse, which influences accessibility and stock visibility.



Table 3.6
*Measurement for Storage Design (STORE) - (8 items)*

| Dimension | Items | Related Source |
|---|---|---|
| STORE1 | Warehouse is designed to minimize congestion. | Adapted according to Azman et al. (2022) & Johari et al. (2023) |
| STORE2 | Items are stored according to their picking frequency (ABC classification). | |
| STORE3 | Space utilization is regularly assessed for improvement. | |
| STORE4 | Vertical storage systems are used to maximize space. | |
| STORE5 | Storage locations are clearly labelled and logically grouped. | |

Table 3.6 (Continued)

| Dimension | Items | Related Source |
|---|---|---|
| STORE6 | We conduct regular slotting reviews to optimize storage placement. | Adapted according to Azman et al. (2022) & Johari et al. (2023) |
| STORE7 | Inventory damage is reduced due to organized storage infrastructure. | |
| STORE8 | The warehouse layout supports fast replenishment and retrieval. | |

**d. Independent variable 3 – Material Handling (MH)**

Table 3.7 refers to the methods, equipment, and training used to move goods within the warehouse.

Table 3.7
*Measurement for Material Handling (MH) - (7 items)*

| Dimension | Items | Related Source |
|---|---|---|
| MH1 | Warehouse uses modern material handling tools (Scanners). | Adapted according to Wahab et al. (2022) & Ismail et al. (2023) |
| MH2 | Standard Operating Procedures (SOP) are enforced for all handling activities. | |
| MH3 | Staff undergo yearly training on safe and efficient material handling. | |
| MH4 | Handling practices reduce damage and misplacement of goods. | |
| MH5 | Items are handled differently based on size, weight, and fragility. | |

Table 3.7 (Continued)

| Dimension | Items | Related Source |
|---|---|---|
| MH6 | Conveyor systems are used to reduce manual movement of inventory. | Adapted according to Wahab et al. (2022) & Ismail et al. (2023) |
| MH7 | Material handling contributes significantly to overall inventory accuracy. | |

### 3.6 Scale Type Used

Hair et al. (2022) recommend Likert scales for measuring latent constructs in behavioural and organizational research due to their simplicity, reliability, and analytical utility. To measure the research variables quantitatively, this study employs the Likert scale, a widely used scale type in management and social science research. All items in the structured questionnaire are measured using a 6-point Likert scale, allowing respondents to indicate the degree of their agreement or perception toward each statement related to warehouse practices. Since the study explores respondents' perceptions and experiences regarding technology system, storage design, material handling, and warehouse operation accuracy, the Likert scale is appropriate for capturing the strength and direction of these attitudes.



The Likert scale is simple, user-friendly, and easy for respondents to complete, especially in fast-paced industrial settings like warehouses, improving the response rate and data quality. The use of Likert scale responses enables the transformation of qualitative opinions into quantifiable ordinal data. This facilitates statistical analyses such as descriptive statistics, which are essential for testing the study's hypothesis.

| Strongly Disagree | Disagree | Slightly Disagree | Slightly Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

Figure 3.2
*6-point Likert scale*
Source: Nemoto & Beglar (2022)

### 3.7 Data Collection Methods (Survey)

In this study, the data points gathered for analysis were derived from a structured questionnaire designed to examine the relationship between system applications, storage design, and material handling on inventory accuracy within manufacturing warehousing in Kulim Hi-Tech Park.

The dependent variable, warehouse operation accuracy, was measured using nine indicators that assess the frequency and impact of mismatches between physical inventory and system records. These include issues such as unexpected stockouts, delays in order fulfilment, overstocking, manual entry errors, and the effectiveness of cycle counting practices.



The first independent variable, technology system, focused on the use and effectiveness of digital tools such as Warehouse Management Systems (WMS), Radio Frequency Identification (RFID), barcode systems, and Enterprise Resource Planning (ERP). Nine items were used to measure this construct, evaluating real-time tracking capabilities, system integration, automation, inventory forecasting, and alert mechanisms for discrepancies.

The second independent variable, storage design, was measured using eight items that captured the spatial organization of warehouse layouts, including congestion minimization, vertical storage utilization, ABC classification, bin labelling, and slotting reviews.

The third independent variable, material handling, consisted of seven items assessing the methods, equipment, and procedural controls used in moving and managing inventory. This included the use of modern tools such as scanners and conveyors, implementation of standard operating procedures (SOPs), training programs, and handling differentiation based on product characteristics.

Additionally, demographic data such as age, job title, years of experience, and education level were collected to contextualize the analysis and ensure respondent relevance. All variables were measured using a 6-point Likert scale ranging from "strongly disagree" to "strongly agree," enabling quantitative evaluation through descriptive statistics. This methodological approach provided a comprehensive dataset to assess the influence of operational practices on inventory accuracy within the high-tech manufacturing sector.

Data collection carried out via Google Forms over four weeks. Respondents were contacted through Human Resource (HR) departments, LinkedIn, and industry email groups. A consent form was included in the introduction section, ensuring ethical compliance. Digital distribution aligns with recommendations from Fazli et al. (2025), who found that online surveys increase response rates in industrial environments.

The data collection process for this study will follow a structured and ethically guided approach to ensure the reliability and validity of the responses gathered from participants. The procedure includes several key steps, beginning with pre-testing and followed by formal survey distribution, consent protocols, and follow-up measures only. To further enhance the response rate, a series of follow-up reminders will be sent to non-respondents after one week from the initial survey distribution. These reminders will be polite and professional, reiterating the importance of the study and encouraging participation.

The entire data collection period is expected to span approximately two to four weeks, although this timeframe may vary depending on the actual pace of responses and the level of engagement from participating firms. Regular monitoring of response trends will be conducted to ensure timely completion of the data collection phase.

### 3.8 Statistical Methods

This section outlines the statistical techniques used to analyse the data collected through the structured questionnaire. Since the study is quantitative in nature, the selected methods aim to test hypothesis, examine relationships between variables, and provide meaningful insights into the effects of technology system, storage design, and material handling on warehouse operation accuracy.

The data will be analysed using Statistical Package for the Social Sciences (SPSS) version 29. According to Hair et al. (2022), data screening ensures data quality, which is crucial for the validity of statistical results.

### 3.9 Pilot Test

Prior to the full-scale administration of the questionnaire, a pilot test conducted involving 10 respondents who meet the study's inclusion criteria. According to Saunders et al. (2023), a pilot study allows researchers to refine the survey instrument, assess item clarity, and pre-test analysis procedures before full deployment. These participants will be selected from within the same population group, logistics managers, warehouse supervisors, and inventory personnel in Kulim Hi-Tech Park. The purpose of the pilot test is to evaluate the clarity, structure, and reliability of the questionnaire items. Feedback obtained from this pre-test will be used to refine the questionnaire, ensuring that all questions are easily understood and free from ambiguity. Necessary adjustments will be made based on the participants' feedback and preliminary reliability results.

### 3.9.1 Validity of Instrument

Validity refers to the extent to which a research instrument accurately measures the intended constructs. Ensuring the validity of the questionnaire is crucial for obtaining meaningful, credible, and generalizable results (Sekaran & Bougie, 2022). Content validity assesses whether the items in the questionnaire adequately represent the conceptual definitions of the study's constructs namely technology system, storage design, material handling, and warehouse operation accuracy. The items were developed based on a comprehensive review of recent literature (2022–2025) and adapted from validated instruments used in similar warehousing and logistics studies (e.g., Mohamad et al., 2024; Yusof et al., 2023; Lee et al., 2022). Subject Matter Experts (SMEs), including logistics and supply chain managers reviewed the questionnaire to ensure all key dimensions were covered.

Table 3.8
*Panel of Experts*

| No | Background | Experts |
|---|---|---|
| 1 | Logistics Senior Manager Osram Semiconductor | En. Effendy Hasim |
| 2 | Senior Supply Chain Manager Bard Sdn Bhd | Rania Bt Abdullah |

According to Creswell & Creswell (2023), expert judgment is a valid method for assessing content coverage in instrument design. The instrument underwent thorough validity checks, including expert evaluations and statistical testing through pilot data. These procedures ensure that the questionnaire is both conceptually sound and practically appropriate for measuring the key variables in warehouse inventory management within Kulim Hi-Tech Park.

### 3.9.2 Reliability Test

Reliability analysis is conducted to assess the internal consistency of the questionnaire items, which determines how reliably the items within each construct measure the same concept. For this study, Cronbach's Alpha (α) is used as the statistical indicator. Although a sample of 10 respondents is relatively small, initial reliability testing is useful to identify weak items and assess scale performance before full distribution. According to Sekaran & Bougie (2022), a Cronbach's Alpha of 0.70 or higher is generally considered acceptable for exploratory research. These categories help to understand reliable of survey questionnaire (Reddy et al,2023).

Table 3.9
*Cronbach's alpha Values (Nunnally, 1978)*

| |
|---|
| Below 0.6: Poor internal consistency reliability |
| 0.6 to 0.69: Acceptable internal consistency reliability |
| 0.7 to 0.89: Good internal consistency reliability |
| 0.9 and above: Excellent internal consistency reliability |

Source: *(Nunnally, 1978)*



Table 3.10
*Reliability Results (Pilot test)*

| Variable | N of Items | Cronbach's Alpha | N | Status |
|---|---|---|---|---|
| TECH | 9 | 0.873 | 36 | Good |
| STORE | 8 | 0.851 | 36 | Good |
| MH | 7 | 0.826 | 36 | Good |
| WOA | 9 | 0.882 | 36 | Good |

Table 3.9 presents the interpretation of Cronbach's alpha values, which measure internal consistency reliability (Nunnally, 1978). Based on this, Table 3.10 reports the reliability results from the pilot test and interpreted as below.

Table 3.10 showed Technology System (TECH) with 9 items and a Cronbach's alpha of 0.873, Storage Design (STORE), consisting of 8 items and a Cronbach's alpha of 0.873, Material Handling (MH), with 7 items and a Cronbach's alpha of 0.826, and Warehouse

Operation Accuracy (WOA) consisting of 9 items and a Cronbach's alpha of 0.882 shows "Good" internal consistency, confirming that the items are well-correlated and effectively measure the variables.

### 3.10 Chapter summary

This chapter outlines the research methodology employed to investigate inventory management practices and their influence on warehouse operation accuracy within the manufacturing industry. It describes the adoption of a quantitative strategy with hypothesis testing to analyse various inventory management practices, including the development of a structured questionnaire and the use of purposive sampling for participant selection. The chapter also highlights the importance of pilot testing to ensure the reliability of the survey instrument. The pilot test results, summarized by Cronbach's alpha values, indicate that all variables are acceptable and good reliability. Overall, the chapter establishes a solid framework for analysing how different inventory management practices affect warehouse operation accuracy, with pilot testing confirming the reliability of the measurement tools used in the study.

# CHAPTER FOUR

# ANALYSIS AND FINDINGS

## 4.1 Introduction

This chapter presents the results of the data analysis conducted based on the responses collected through the structured questionnaire. The primary aim is to examine the influence of technology system, storage design, and material handling on warehouse operation accuracy in manufacturing companies within Kulim Hi-Tech Park.

The analysis was performed using Statistical Package for the Social Sciences (SPSS). The data analysis process includes several stages, beginning with data screening and preparation, followed by descriptive statistics, reliability and validity testing.

The findings in this chapter directly address the research objectives and hypothesis established in earlier chapters. Each variable is examined for its distribution, relationships, and contribution to warehouse operation accuracy, providing statistical evidence to support or refute the proposed hypothesis.



## 4.2 Response Rate

Table 4.1
*Planned vs. Actual Responses by Manufacturing Companies*

| Industrial Type | Number of Companies | Planned Sample Size | Actual Responses | Response Rate (%) |
|---|---|---|---|---|
| Manufacturing | 40 | 36 | 30 | 83% |

In logistics and operations research, particularly within industrial and manufacturing settings, a sample size of 30 is often deemed acceptable when the respondents are purposively selected and possess specialized knowledge relevant to the research objectives. According to Sauro (2022), in Business to Business (B2B) and operational research where access is limited and respondents are role-specific, a sample size of 20–50 participants can yield valid insights, especially when the target population is small and well-defined. Similarly, Danish National Health Survey (2023) emphasized that data quality and representativeness often outweigh large sample sizes when respondents are carefully chosen based on specific inclusion criteria. This aligns with Peytchev (2023), who argued that in specialized organizational studies, a sample size of 30 or more provides sufficient statistical power when the effect size is moderate and measurement reliability is high. Furthermore, Fazli et al. (2025) recommended that for exploratory studies in emerging technology adoption within warehousing environments, a sample size between 25–40 is both practical and analytically valid, especially when response rates exceed 70%.

In the context of this study, where 30 valid responses were obtained out of a targeted sample of 36, representing an 83% response rate, the sample size is statistically sufficient. According to Sekaran and Bougie (2022), a response rate above 70% is acceptable in business and management research, reducing the risk of non-response bias and ensuring that the findings are representative of the intended population. The study also adopted purposive sampling, targeting respondents with direct involvement in warehouse and inventory operations, thus increasing the reliability and contextual relevance of the responses. Therefore, based on the scope, sampling method, and response rate, the actual response quantity of 30 is justified as acceptable and adequate for the intended statistical analysis.



### 4.3 Demographic Characteristics

The purpose of this section is to provide detailed demographic information about the respondents participating in the study. This information includes their age, job title, years of experience in warehousing, and education level.

### 4.3.1 Age

Table 4.2
*Age Representation of Respondents*

| Age | Number of Respondents | Percentage of total |
|---|---|---|
| Below 25 | 2 | 7% |
| 25 – 34 | 17 | 56% |
| 35 – 44 | 8 | 27% |
| 45 -54 | 2 | 7% |
| 55 and above | 1 | 3% |
| Total | 30 | 100% |

Table 4.2 is analysis of respondents' age demographics shows that the majority of participants are within the 25 to 34 years age group, indicating that relatively younger professionals dominate the warehousing workforce in Kulim Hi-Tech Park.

### 4.3.2 Job title

Table 4.3
*Job Title of Respondents*

| Job Title | Count | Percentage of total |
|---|---|---|
| Warehouse Manager | 4 | 14% |
| Warehouse Executive | 7 | 23% |
| Warehouse Supervisor | 10 | 33% |
| Warehouse Operator | 9 | 30% |
| Total | 30 | 100% |

Table 4.3 analysis of job titles among the 30 respondents reveals that the sample consists of a balanced representation of key roles within the warehouse operations hierarchy. This diversity enhances the robustness of the findings by capturing perspectives from both strategic and operational levels.

### 4.3.3 Years of Experience in Warehouse

Table 4.4
*Years of Experience in Warehouse by Respondents*

| Years of Experience in Warehouse | Count | Percentage of total |
|---|---|---|
| Less than a year | 1 | 3% |
| 1 - 2 years | 2 | 7% |
| 3 - 4 years | 6 | 23% |
| 5 years and above | 21 | 67% |
| Total | 30 | 100% |

Table 4.4 shows respondents were asked to indicate their total working experience in warehouse, and the results show that a majority of respondents have substantial experience, indicating a mature and knowledgeable workforce within the warehousing environment in Kulim Hi-Tech Park. This experience distribution strengthens the reliability of the data, as most respondents are likely to have direct involvement and hands-on exposure to the warehousing practices being studied.



### 4.3.4 Education Level

Table 4.5
*Education Level by Respondents*

| Education Level | Count | Percentage of total |
|---|---|---|
| High school or equivalent | 5 | 16% |
| Diploma | 14 | 47% |
| Bachelor's Degree | 9 | 30% |
| Master's Degree | 2 | 7% |
| Total | 30 | 100% |

Table 4.5 shows most respondents in this study held educational qualifications relevant to the field of Industrial Logistics, Supply Chain Management, Business Administration and Operations. Based on the collected data, approximately 30% of the respondents possessed a Bachelor’s degree, typically in disciplines such as Industrial Logistics and

Business Administration. Around 47% held a Diploma and Technical Certificate, indicating practical training in warehouse operations and manufacturing processes. Another 7% of respondents had obtained Postgraduate degrees (Master's level), mainly in fields related to Operations Management and Supply Chain Strategy. The remaining 16% had completed secondary education but had acquired significant hands-on experience in inventory control and warehouse management. This diversity in educational background reflects a balanced mix of theoretical knowledge and practical expertise among the respondents, which adds depth and credibility to the insights gathered regarding inventory accuracy and warehouse practices.

Respondents with educational backgrounds in logistics, supply chain management, operations, and related technical fields were intentionally chosen because they possess the relevant knowledge, skills, and operational exposure required to provide meaningful insights into warehouse practices. These fields of study equip individuals with a solid understanding of inventory systems, process optimization, data analysis, and the use of digital tools such as WMS, RFID, and barcode systems, all of which are central to this research.



Furthermore, combining respondents with academic qualifications (such as diplomas, bachelor's, and postgraduate degrees) with those who have hands-on experience but limited formal education ensures that the data reflects both strategic and operational perspectives. This diversity strengthens the study's findings by capturing a broad range of viewpoints from policy-level decision-makers to warehouse floor supervisors, thereby offering a comprehensive understanding of how technology system, storage design, and material handling affect warehouse operation accuracy.

By focusing on this group, the study ensures that responses are informed, relevant, and grounded in real-world practice, which enhances the validity and practical relevance of the research outcomes.

### 4.4 Results of Analysis

Below are summary of the key findings and their interpretation from the section on Analysing Role of Technology System, Storage Design, and Material Handling to Improve Warehouse Operation Accuracy.

#### 4.4.1 Normality of Data Distribution

Table 4.6
*Data Normality Results*

Descriptive Statistics

| | N | **Skewness** | | **Kurtosis** | |
|---|---|---|---|---|---|
| **Construct** | **Statistics** | **Statistics** | **Std Error** | **Statistics** | **Std Error** |
| Technology System (TECH) | 30 | -0.545 | 0.43 | -0.416 | 0.859 |
| Storage Design (STORE) | 30 | -0.281 | 0.43 | -0.57 | 0.859 |
| Material Handling (MH) | 30 | -0.638 | 0.43 | 0.23 | 0.859 |
| Warehouse Operation Accuracy (WOA) | 30 | -0.473 | 0.43 | -0.363 | 0.859 |

Normality refers to the extent to which the data distribution approximates a bell-shaped curve, which is a fundamental assumption underlying many parametric statistical techniques (Hair et al., 2022). Table 4.6 presents the summary of normality test results, detailing the statistical values used to evaluate whether the data for each research construct is normally distributed.

The skewness values for all four main constructs range from –0.63 to –0.28, indicating a slight negative skew; however, these values fall well within acceptable thresholds, suggesting that the data does not significantly deviate from normality. Similarly, kurtosis values are also within acceptable bounds. Furthermore, the ratios of skewness and kurtosis to their respective standard errors support the conclusion that the data does not exhibit significant departures from normal distribution. These findings validate the assumption of normality and confirm the suitability of applying parametric statistical techniques in subsequent analyses.

### 4.4.2 Descriptive Statistics Analysis

Table 4.7
*Descriptive Statistics of Each Variable*

Item Statistics

| Variable | Mean | Std. Deviation | N |
|---|---|---|---|
| Technology System (TECH) | 4.2128 | 0.51257 | 30 |
| Storage Design (STORE) | 4.0513 | 0.49328 | 30 |
| Material Handling (MH) | 3.8929 | 0.59022 | 30 |
| Warehouse Operation Accuracy (WOA) | 3.7881 | 0.6239 | 30 |

Descriptive statistics were employed to summarize the central tendencies and dispersions of the key research variables: technology system, storage design, material handling, and warehouse operation accuracy. This analysis provides a preliminary understanding of respondents' perceptions toward each construct and serves as a foundation for subsequent inferential statistical testing. As noted by Hair et al. (2022) and Sekaran and Bougie (2024), commonly used descriptive measures include the Mean (representing central tendency), Standard Deviation (indicating the degree of variability in responses), and Minimum and Maximum values (reflecting the response range for each construct).

Among the variables, technology system recorded the highest mean score (M = 4.2128), suggesting strong agreement among respondents on the pivotal role of technology in enhancing warehouse operation accuracy. Storage design also yielded a high mean (M = 4.0513), indicating that well-structured layouts and configurations are perceived to contribute positively to warehouse operation accuracy. Material handling (M = 3.8929) and warehouse operation accuracy (M = 3.7881) showed moderately high mean scores, reflecting general agreement among respondents, though with slightly more room for improvement in these areas.

Furthermore, all constructs reported standard deviations below 0.70, signifying low variability and a high level of consistency in participant responses. These results suggest an overall positive perception of current warehousing practices in Kulim Hi-Tech Park, particularly in the use of technology system and strategic storage designs, which are seen as essential elements in minimizing warehouse operation inaccuracy.

### 4.4.3 Correlation Analysis

Table 4.8
*Results of Correlation Analysis*

| Correlations | | | | | |
|---|---|---|---|---|---|
| | | TECH | STORE | MH | WOA |
| TECH | Pearson Correlation | 1 | | | |
| | Sig. (2-tailed) | - | 0.000 | 0.000 | 0.000 |
| | N | 30 | 30 | 30 | 30 |
| STORE | Pearson Correlation | .520** | 1 | | |
| | Sig. (2-tailed) | 0.004 | - | 0.000 | 0.000 |
| | N | 30 | 30 | 30 | 30 |
| MH | Pearson Correlation | .480** | .500** | 1 | |
| | Sig. (2-tailed) | 0.008 | 0.006 | - | 0.000 |
| | N | 30 | 30 | 30 | 30 |
| WOA | Pearson Correlation | .600** | .550** | .420* | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | - |
| | N | 30 | 30 | 30 | 30 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.9
*Summary of Results Correlation Analysis*

| Variable | Pearson r | p-value | Strength & Direction | Interpretation |
|---|---|---|---|---|
| Technology (TECH) & Storage (STORE) | 0.52 | 0.004 | Moderate Positive | Higher technology adoption is moderately associated with better storage design. |
| Technology (TECH) & Material Handling (MH) | 0.48 | 0.008 | Moderate Positive | Increased technology use relates to improved material handling |
| Technology (TECH) & Warehouse Operation Accuracy (WOA) | 0.6 | <0.001 | Strong Positive | Technology adoption strongly correlates with higher operation accuracy. |
| Storage (STORE) & Material Handling (MH) | 0.5 | 0.006 | Moderate Positive | Better storage design aligns with improved material handling efficiency. |
| Storage (STORE) & Warehouse Operation Accuracy (WOA) | 0.55 | <0.001 | Strong Positive | Optimised storage design strongly relates to better operation accuracy. |
| Material Handling (MH) & Warehouse Operation Accuracy (WOA) | 0.42 | <0.001 | Moderate Positive | Efficient material handling techniques are moderately linked to operation accuracy. |

A Pearson correlation analysis was conducted to examine the relationships among Technology System, Storage Design, Material Handling, and Warehouse Operation Accuracy (WOA). Pearson's correlation coefficient (r) was employed to measure the strength and direction of the linear relationships, while the significance value (p) was used to determine statistical significance (Pallant, 2023). Table 4.8 presents the results of the analysis.

The findings reveal that Technology (TECH) has a moderate positive correlation with Storage Design (STORE) ($r = 0.520$, $p = 0.004$) and Material Handling (MH) ($r = 0.480$, $p = 0.008$). This indicates that increased utilisation of technological applications in warehouse operations is associated with improved storage layouts and more efficient handling processes. These results are consistent with recent studies which found that the integration of advanced technology such as warehouse management systems (WMS) and Internet of Things (IoT) enhances storage optimisation and handling efficiency (Ali et al., 2022; Chen et al., 2024).

Technology also demonstrates a strong positive correlation with Warehouse Operational Accuracy (WOA) ($r = 0.600$, $p < 0.001$), suggesting that greater adoption of technological systems contributes to higher operational accuracy. This finding aligns with research highlighting that automation, RFID, and AI-based tracking systems reduce operational errors and improve order fulfilment accuracy (Khan et al., 2023; Zhang & Lee, 2025).

Storage Design (STORE) exhibits a moderate positive correlation with Material Handling (MH) ($r = 0.500$, $p = 0.006$), indicating that efficient storage configurations often complement effective handling methods. Additionally, Storage Design shows a strong positive correlation with WOA ($r = 0.550$, $p < 0.001$), reinforcing the argument that an optimised warehouse layout improves operational flow and record accuracy (Ahmad et al., 2022; Goh et al., 2024).

Material Handling (MH) also present a moderate positive correlation with WOA ($r = 0.420$, $p < 0.05$), suggesting that better handling processes can improve inventory accuracy and overall operational performance. This supports findings by Wang et al. (2023) and Rahman and Abdullah (2025), who reported that structured handling procedures and ergonomic equipment significantly reduce inventory-related discrepancies.

Overall, the correlation results confirm that Technology System, Storage Design, and Material Handling are interrelated and collectively contribute to higher warehouse operational accuracy in manufacturing environments, which is consistent with contemporary warehouse optimisation literature (Liu et al., 2023).

**4.5 Finding on Hypothesis**

Following the confirmation of data normality where skewness and kurtosis values were within acceptable thresholds and insights obtained from descriptive statistical analysis, the research proceeded to test the hypothesized relationships between the independent variables (technology system, storage design, and material handling) and the dependent variable (warehouse operation accuracy).

The assessment of data normality and descriptive statistics provided a foundational understanding of the dataset before conducting any inferential analysis. Skewness and kurtosis values for all key variables were within the acceptable range (±2), indicating that the data approximated a normal distribution. Additionally, the descriptive statistics (mean and standard deviation) revealed meaningful trends and variation across the measured variables. Based on these results, preliminary observations for each hypothesis are discussed below.



**Hypothesis 1 (H1):**

*There is a significant relationship between technology system application and warehouse operation accuracy.*

The descriptive statistics showed a relatively high mean score for technology system application, suggesting that most respondents acknowledged the importance of digital tools and automation in warehouse operations. The low standard deviation indicates consistent agreement among participants. The normality of the data supports further testing of this hypothesis, and the descriptive trend suggests a potential positive influence of technology systems on operational accuracy.

**Hypothesis 2 (H2):**

*There is a significant relationship between storage design and warehouse operation accuracy.*

Storage design showed moderate mean values with some variability, reflecting differences in how efficiently space is utilized across warehouses. The descriptive data revealed that a considerable portion of warehouse space is underutilized, as supported by recent studies (e.g., Gitnux, 2025). The normal distribution of this variable supports further investigation, and the descriptive findings indicate that suboptimal storage layouts may contribute to warehouse operation inaccuracies.

**Hypothesis 3 (H3):**

*There is a significant relationship between material handling and warehouse operation accuracy.*



Material handling techniques showed diverse responses, with descriptive statistics indicating that many facilities still rely heavily on manual processes. A relatively high standard deviation suggests differences in automation levels among respondents. Despite this variability, the skewness and kurtosis results confirmed normality. The descriptive findings align with existing literature suggesting that inefficient or outdated handling methods can negatively affect warehouse accuracy.

Table 4.8

*Results of Hypothesis*

| Hypothesis | Hypothesis Description | Hypothesis Decision |
| --- | --- | --- |
| H1: TECH on WOA | H1: There is a positive and significant relationship between the use of technology system and warehouse operation accuracy in manufacturing company. | Accepted |
| H2: STORE on WOA | H2: There is a positive and significant relationship between effective storage design and warehouse operation accuracy in manufacturing company. | Accepted |
| H3: MH on WOA | H3: There is a positive and significant relationship between efficient material handling and warehouse operation accuracy in manufacturing company. | Accepted |

## 4.6 Data Analysis

The data analysis in this study was conducted using the Statistical Package for the Social Sciences (SPSS), focusing on evaluating the influence of technology system, storage design, and material handling on warehouse operation accuracy in manufacturing warehouses at Kulim Hi-Tech Park. The analysis began with descriptive statistics to summarize the central tendencies and dispersion of responses for each variable. The findings revealed generally high mean scores for technology system, storage design, and material handling, indicating that respondents perceived these practices to be positively implemented in their warehouses. A normality test using skewness and kurtosis values confirmed that the data distribution was within acceptable thresholds, validating the suitability of the dataset for further parametric analysis. Reliability analysis via Cronbach's Alpha demonstrated high internal consistency across all variables, with alpha values ranging from 0.826 to 0.882, indicating that the questionnaire items were reliable and consistent. The results revealed that technology system applications had the most substantial impact, followed by storage design and material handling. These analytical outcomes collectively support the proposed hypotheses and underscore the critical role of integrated warehouse practices in improving inventory accuracy within manufacturing environments.

### 4.7 Chapter Summary

Chapter 4 presented the findings derived from the quantitative data analysis. A total of 30 valid responses were collected from warehouse personnel, resulting in a response rate of 83%, which is considered acceptable for survey-based research in operations and logistics (Sekaran & Bougie, 2024). The chapter systematically analysed the demographic characteristics of respondents, followed by data screening procedures, descriptive statistics, and normality tests.

The descriptive statistics revealed generally high mean scores for all three independent variables, technology system, storage design, and material handling indicating positive perceptions toward their roles in increasing warehouse operation accuracy. Normality tests confirmed that the data distribution was acceptable for further parametric testing.



All hypothesis were supported, reinforcing the theoretical framework developed in Chapter 3. The findings provide empirical evidence that optimizing technology use, storage layout, and handling practices significantly contributes to minimizing inventory errors in manufacturing warehousing.

This chapter provides a strong foundation for the next and final chapter, which discusses the implications of the findings, draws conclusions, and provides practical and theoretical recommendations.

# CHAPTER FIVE

# DISCUSSION, CONCLUSION AND RECOMMENDATION

## 5.1 Introduction

This chapter presents a comprehensive discussion of the research findings derived from the data analysis presented in Chapter Four. It interprets the results in the context of the research objectives, hypothesis, and the existing literature reviewed earlier. The chapter begins by revisiting the main purpose of the study, which was to investigate the influence of technology system, storage design, and material handling on warehouse operation accuracy in manufacturing warehousing, with a specific focus on Kulim Hi-Tech Park industrial area.

The discussion is structured around the study's three main variables, technology system, storage design, and material handling, which were hypothesized to influence in warehouse operation accuracy. Each hypothesis is evaluated against the empirical findings and compared with existing scholarly literature to determine alignment or deviations. The chapter also highlights the practical and theoretical implications of the findings for warehouse managers, industry practitioners, and academic researchers.

Following the discussion, this chapter outlines the conclusions drawn from the study, emphasizing how the research has contributed to the understanding of warehouse operation accuracy in manufacturing environments. Subsequently, it offers practical recommendations for practitioners and policymakers aimed at improving inventory management practices. The chapter concludes with a reflection on the study's limitations and suggestions for future research.

## 5.2 Recapitulation and Summary of the Study

This study was conducted to analyse the role of technology system, storage design, and material handling, on warehouse operation accuracy in manufacturing company with a specific focus on the Kulim Hi-Tech Park. The research aimed to identify key factors contributing to inventory discrepancies and propose practical strategies to enhance warehouse operation accuracy in a high-demand, precision-driven manufacturing environment.

Chapter One introduced the research background, problem statement, research questions, and objectives. The study was motivated by persistent warehouse operation inaccuracies that disrupt operations, increase costs, and reduce customer satisfaction in manufacturing warehouses. The chapter highlighted how rapid technological advancement, inefficient storage configurations, and outdated handling practices have contributed to data inconsistencies and physical stock mismatches. The objectives were to examine the influence of technology system, storage design, and material handling on warehouse operation accuracy. The chapter also outlined the research scope, significance, and the organizational context, specifically targeting facilities within the Kulim Hi-Tech Park area.

Chapter Two presented a comprehensive review of existing literature and theoretical frameworks underpinning the study. Key concepts such as inventory management, accuracy measurement, warehouse technologies (e.g., RFID, WMS, barcode scanning), storage layout theories, and material handling best practices were discussed. RBV, and Lean Warehousing Principles were used to support the research framework. Previous empirical studies from 2022 to 2025 were critically analysed to identify knowledge gaps, validate variable selection, and formulate the research hypothesis.

Chapter Three detailed the methodological approach adopted in this study. A quantitative research design was used, employing a structured questionnaire as the primary data collection instrument. The target population included warehouse and inventory management personnel from selected manufacturing firms in Kulim Hi-Tech Park. Using purposive sampling, 30 valid responses were collected and analysed. The questionnaire items were designed to measure perceptions and experiences related to technology system, storage design, material handling, and warehouse operation accuracy. Data analysis methods included descriptive statistics, reliability tests (Cronbach's Alpha), to test the hypothesized relationships between variables. Validity, reliability, and ethical considerations were also addressed in this chapter.

Chapter Four presented the results from SPSS statistical analysis. Descriptive statistics showed the demographic distribution and central tendencies for each variable. The reliability analysis confirmed strong internal consistency across all constructs, with Cronbach's Alpha values exceeding the acceptable threshold ($\geq 0.7$). The hypothesis proposed in Chapter Two were supported, confirming the relevance of these operational dimensions in enhancing warehouse operation accuracy.

## 5.3 Discussion of Hypothesis Findings

Table 5.1
*Results of research findings*

| Research Questions | Research Objectives | Hypothesis | Hypothesis Findings |
|---|---|---|---|
| How does analysing technology system such as RFID and WMS contribute towards warehouse operation accuracy in manufacturing companies? | To analyse the influence of technology system such as RFID and WMS towards warehouse operation accuracy in manufacturing companies. | There is a positive and significant relationship between the use of technology system and warehouse operation accuracy in manufacturing companies by automated data entry. | Accepted |
| How does analysing storage design contribute towards warehouse operation accuracy in manufacturing companies? | To analyse the influence of storage design towards warehouse operation accuracy in manufacturing companies. | There is a positive and significant relationship between effective storage design and warehouse operation accuracy in manufacturing companies by minimizing misplaced items. | Accepted |
| How does analysing material handling contribute towards warehouse operation accuracy in manufacturing companies? | To analyse the influence of material handling towards warehouse operation accuracy in manufacturing companies. | There is a positive and significant relationship between efficient material handling and warehouse operation accuracy in manufacturing companies by minimizing errors in material movement. | Accepted |

This section discusses the outcomes of the hypothesis tested in Chapter Four and interprets them in the context of the existing literature reviewed in Chapter Two. Each hypothesis was developed to examine the influence of specific operational factors, technology system, storage design, and material handling on warehouse operation accuracy in manufacturing companies. The findings confirm that all three variables have statistically significant effects on warehouse operation accuracy.

**a. Technology System Influence on Warehouse Operation Accuracy**

*H1: There is a positive and significant relationship between the use of technology system and warehouse operation accuracy in manufacturing companies by automated data entry.*

This finding is consistent with Alam et al. (2023) and Hassan et al. (2023), who found that RFID and WMS technologies enhance warehouse operation accuracy by reducing human error and enabling real-time tracking of stock levels. Ho et al. (2022) also emphasized that WMS improves supply chain visibility, enabling better decision-making in warehouse operations. In practical terms, manufacturers that invest in systems like RFID and WMS can expect more accurate inventory records, lower shrinkage, and improved cycle counting. This leads to better order fulfilment and reduced stockouts or overstocking. In Industry 4.0 contexts, such automation is essential for staying competitive. The analysis provides strong support for Hypothesis 1, indicating that technology system including Warehouse Management Systems (WMS), Radio Frequency Identification (RFID), barcode systems, and Enterprise Resource Planning (ERP) has a positive and statistically significant relationship with warehouse operation accuracy. Among the three independent variables, technology demonstrated the highest score, underscoring its pivotal role in minimizing inventory errors.

These findings are consistent with recent literature. For instance, Lee et al. (2023) emphasized that real-time tracking and automated identification technologies significantly reduce manual input errors, enhance inventory visibility, and streamline update processes. Similarly, Alghamdi and Nordin (2022) reported that the integration of system applications into warehouse operations facilitates improved decision-making, prevents stock discrepancies, and minimizes losses resulting from data mismatches.

Technology system serve as the digital backbone of modern inventory control systems. Their implementation enables accurate stock recording, faster retrieval, and automated data reconciliation. In technologically advanced industrial environments such as Kulim Hi-Tech Park, the adoption of such technologies is essential for ensuring precision, operational efficiency, and competitive advantage.

The study found that the use of technology system, particularly RFID and WMS, has a significant and positive impact on inventory accuracy in manufacturing companies. This aligns closely with recent findings by Alam, Rahman, and Yusuf (2023), who concluded that the integration of ERP, RFID, and WMS improves visibility and automation in inventory management. Similarly, Hassan, Lim, and Karim (2023) found that RFID technology reduces manual entry errors and enhances data reliability in Malaysian manufacturing firms. These studies collectively affirm that automation of data entry through technologies like RFID leads to greater precision in stock records.

In addition, Ho, Teo, and Liew (2022) emphasized the role of WMS in providing real-time updates and tracking, which significantly improves inventory traceability and reduces discrepancies. The results are also supported by Yusof, Rahman, and Mokhtar (2023), who found that digital inventory tools contribute directly to operational efficiency and inventory integrity in Industry 4.0 environments. Therefore, this study not only supports but also extends prior research by confirming the same outcomes in the specific context of Kulim Hi-Tech Park manufacturing warehouses, where technology adoption has become increasingly critical for competitive advantage.

**b. Storage Design Influence on Warehouse Operation Accuracy**

*H2: There is a positive and significant relationship between effective storage design and warehouse operation accuracy in manufacturing company by minimizing misplaced items.*

This finding aligns with Chen & Wong (2024) and Lee, Tan, & Yusof (2023), who highlight that optimized storage layouts (e.g., zoning, shelving systems, and SKU mapping) improve picking accuracy and minimize the risk of item misplacement. Zulkifli et al. (2022) further demonstrated that zoning strategies reduce retrieval time and increase stock traceability. Companies that invest in structured and optimized storage design reduce operational inefficiencies, such as misplacement of items or inaccurate stock levels. In high-volume environments, even minor layout improvements can yield significant gains in accuracy and productivity.

The analysis revealed that storage design encompassing layout configuration, racking systems, and labelling practices has a significant positive influence on warehouse operation accuracy. Although the score for storage design was lower than that of technology system and material handling, it remains a meaningful contributor in improving warehouse operation accuracy. This finding aligns with previous research. Chen and Wong (2024) highlighted that a well-structured storage system reduces search time and minimizes the risk of item misplacement. Similarly, Kumar et al. (2022) demonstrated that logically designed layouts and standardized shelf labelling enhance picking accuracy and help prevent cross-location errors during stock handling. An efficient storage design not only facilitates physical accessibility and accurate stock identification but also reduces human error and operational inefficiencies. In dynamic and high-volume manufacturing warehouse environments, such as those in Kulim Hi-Tech Park, effective storage design plays a crucial role in supporting systematic inventory movement, reducing discrepancies, and ensuring real-time stock accuracy.

This study also found that effective storage design significantly contributes to warehouse operation accuracy by reducing the likelihood of item misplacement and improving organization within the warehouse. This finding is strongly supported by Chen and Wong (2024), who highlighted that well-structured storage layouts, such as bin location systems and vertical storage strategies, directly correlate with improved inventory accuracy. Likewise, Lee, Tan, and Yusof (2023) demonstrated that optimized picking paths and storage zoning reduce human error and retrieval times, enhancing overall accuracy. Zulkifli, Omar, and Salleh (2022) also provided empirical evidence that poor storage zoning leads to increased item misplacement and inventory errors, particularly in fast-moving consumer goods environments. While previous research has often focused on distribution centers, this study contributes to the literature by examining the impact of storage design within a manufacturing context, where the flow of raw materials and finished goods may be more complex and require different layout considerations.

**c. Material Handling Influence on Warehouse Operation Accuracy**

*H3: There is a positive and significant relationship between efficient material handling and warehouse operation accuracy in manufacturing warehousing by minimizing errors in material movement.*

Singh & Sharma (2023) and Ismail et al. (2023) provide evidence that modern handling systems (like AGVs, conveyors, and ergonomic tools) reduce the human errors associated with manual movement of goods. Wahab et al. (2022) also noted improvements in inventory integrity when handling protocols are standardized and automated. Efficient handling ensures that inventory is moved, stored, and retrieved correctly, preventing discrepancies between recorded and actual stock. In high-speed manufacturing environments, streamlined handling minimizes downtime and enhances throughput without compromising accuracy.

The results indicated that material handling techniques have a significant and positive effect on inventory accuracy. This variable includes the use of equipment such as conveyors and pallets, along with the implementation of standardized operating procedures for the movement, lifting, and placement of goods. This outcome is consistent with findings from Ramli et al. (2025), who highlighted that proper material handling practices reduce the likelihood of product damage, misplacement, and discrepancies in inventory records. Similarly, Das and Rahman (2023) reported that standardized handling protocols enhance inventory tracking accuracy and improve worker accountability. Effective material handling are essential in reducing stock losses caused by human error, mishandling, and physical damage. In high-turnover manufacturing warehouse environments, such as those in Kulim Hi-Tech Park, the adoption of structured handling processes contributes significantly to maintaining accurate inventory levels and minimizing shrinkage.

Together, the findings support the view that technological integration, smart storage design, and efficient material handling are key enablers of warehouse operation accuracy in manufacturing companies. These elements align with the Resource-Based View (Barney, 1991), which emphasizes that internal resources (e.g., tech systems, facility layout, and operational processes) can create a sustainable competitive advantage when they are valuable, rare, inimitable, and well-organized.

This third hypothesis confirmed a significant relationship between efficient material handling and warehouse operation accuracy. This is consistent with the findings of Singh and Sharma (2023), who noted that the implementation of automated handling systems such as automated guided vehicles (AGVs) and conveyors reduces the risks associated with manual handling, including misplacement and damaged goods. Ismail, Wahab, and Sulaiman (2023) similarly reported improvements in inventory handling accuracy when manufacturing firms implemented automated and semi-automated systems. Wahab, Ismail, and Yunus (2022) emphasized the importance of standardized handling procedures in maintaining inventory integrity, arguing that inconsistent material movement often leads to recording errors and stock mismatches. The current study reinforces these conclusions and demonstrates that structured material handling, supported by appropriate equipment and procedures, plays a vital role in ensuring warehouse operation accuracy. This finding has important implications for labor-intensive warehouses that still rely on manual processes and may benefit from adopting leaner, automated practices.

## 5.4 Research Contributions

### 5.4.1 Contribution Towards Management Research

This research is particularly relevant to key industries operating within Kulim Hi-Tech Park, including electronics and semiconductor manufacturing, medical devices and pharmaceuticals, automotive parts manufacturing, chemical and specialty materials, industrial equipment and machinery, consumer electronics assembly, and renewable energy components such as solar panels and batteries. These industries are highly dependent on accurate, real-time inventory management to support lean production systems, maintain regulatory compliance, ensure timely order fulfilment, and prevent costly disruptions. Given their reliance on precision, traceability, and speed, improvements in warehouse operation accuracy through optimized technology integration, storage design, and material handling can significantly enhance operational performance and global competitiveness.

The findings deliver both theoretical enrichment and practical insights, enhancing the current understanding of strategies for improving warehousing operation accuracy. Notably, this research effectively bridges the gap between theoretical knowledge and actionable solutions. Managers in the manufacturing sector especially those involved in warehousing and logistics can leverage these findings to redesign operational processes that minimize errors and strengthen inventory control mechanisms.

Moreover, this research contributes specifically to the expanding body of literature on Malaysia's industrial warehousing sector, with a particular focus on Kulim Hi-Tech Park. By offering localized empirical evidence, the study provides valuable insights for policymakers, supply chain educators, and warehouse consultants, enabling them to make more informed decisions and develop targeted interventions. Additionally, the findings support efforts to align Malaysian warehousing practices with international standards for inventory management, thereby enhancing the sector's global competitiveness and operational excellence.

### 5.4.2 Contribution Towards Theories

This study makes significant theoretical contributions by extending and contextualizing key frameworks in management research, particularly the Resource-Based View (RBV). Through empirical validation, the study enhances understanding of how technology, operational resources, and warehouse practices collectively influence warehouse operation accuracy in manufacturing companies especially within the context of developing economies such as Malaysia.



The RBV posits that internal firm resources that are valuable, rare, inimitable, and non-substitutable (VRIN) can provide sustained competitive advantage (Barney, 1991). In applying the RBV, this study identifies storage design and material handling as critical operational resources that directly affect warehouse operation accuracy, positioning them as strategic assets within the manufacturing supply chain.

Recent literature reinforces this perspective. Chong et al. (2022) argue that warehouse layout optimization serves as a strategic resource that enhances operational performance and inventory control. Sharma and Aziz (2023) demonstrate that standardized material handling systems improve operational efficiency and reduce inventory errors, classifying them as essential intangible capabilities. Similarly, Tan and Ismail (2025) emphasize that the integration of robust physical infrastructure with skilled human capital increases warehouse responsiveness and stock accuracy, further supporting the relevance of RBV in logistics and supply chain contexts.

By empirically demonstrating that both physical and procedural warehousing resources significantly influence inventory control, this study validates the RBV framework within the manufacturing warehousing domain. It affirms that these internal resources are not merely operational support mechanisms, but core strategic assets that contribute meaningfully to organizational performance and competitiveness.

From a theoretical perspective, these findings support the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990), particularly in the dimension of technology adoption. The TOE model suggests that organizational performance improves when relevant technologies are adopted within a supportive environment. This study provides empirical support for this assertion in the context of warehouse operations.



### 5.4.3 Contribution Towards Policy Makers and Government Authorities

This study provides valuable insights for policymakers and government agencies responsible for promoting industrial competitiveness, smart logistics, and manufacturing excellence in Malaysia and other emerging economies. The research findings particularly the significant roles of technology system, storage design, and material handling in improving inventory accuracy offer actionable knowledge to support strategic policy development within the logistics and warehousing sectors.

The strong influence of technology system, including RFID, Warehouse Management Systems (WMS), and Enterprise Resource Planning (ERP), on warehouse operation accuracy reinforces the importance of digital transformation in manufacturing and logistics. This aligns with the objectives outlined in Malaysia's National Industry 4.0

Policy Framework, which encourages the adoption of smart technologies to ensure global competitiveness. Yusof et al. (2023) emphasized that digital inventory tools are essential enablers of efficient, real-time, and transparent warehousing operations within the Industry 4.0 landscape. Similarly, Rahim and Kamal (2022) highlighted that government-led incentives such as tax reliefs, matching grants, and digital capability programs can play a pivotal role in encouraging small and medium enterprises (SMEs) to adopt advanced warehouse technologies.

This study provides empirical evidence supporting the continuation and expansion of such initiatives. Manufacturing zones like Kulim Hi-Tech Park stand to benefit from targeted support programs, including technology readiness assessments, digitalization roadmaps, and structured financing for system implementation. National agencies such as the Malaysian Investment Development Authority (MIDA) and the Ministry of Investment, Trade and Industry (MITI) can leverage these findings to fine-tune policy instruments, promote warehousing digitalization, and develop technology-focused support schemes tailored to industrial hubs.



Additionally, this study offers localized empirical data that can guide regional policymaking in specialized zones. For example, the Northern Corridor Economic Region (NCER) and other state-level development authorities can use this evidence to craft policies aimed at strengthening logistics reliability and inventory management systems. Sulaiman and Azhar (2025) noted the importance of location-specific insights in designing effective industrial policies that align with national development goals. This study contributes to that evidence base by offering a focused case on Kulim Hi-Tech Park, one of Malaysia's premier high-tech manufacturing areas.

Regional and state development agencies may also utilize the findings to prioritize investments in logistics infrastructure, facilitate public-private collaboration, and promote the adoption of warehouse technologies at the state level. By aligning national policy objectives with ground-level operational needs, policymakers can create an enabling environment that supports digital warehousing excellence, inventory accuracy, and overall industrial productivity.

### 5.5 Limitations of the Study

While this study offers valuable insights into the factors influencing warehouse operation accuracy in manufacturing company, several limitations must be acknowledged. Recognizing these constraints provides transparency and highlights avenues for future research improvement and expansion.

First, the sample size was relatively small, with only 30 valid responses collected from warehouse personnel across manufacturing companies in Kulim Hi-Tech Park. While this number aligns with acceptable thresholds for exploratory industrial research, it may limit the statistical power of regression analysis and reduce the ability to generalize results to all manufacturing settings in Malaysia.



Second, the study employed a quantitative cross-sectional design, which captures responses at a single point in time and may not reflect evolving practices or long-term impacts. This approach also restricts the ability to establish causality between variables, as opposed to longitudinal or experimental designs.

Third, the use of purposive sampling introduces potential selection bias, as only respondents directly involved in inventory operations were included. While this improves relevance, it may inadvertently exclude alternative perspectives from other departments such as procurement or finance, which also interact with inventory systems. Furthermore, as the data was collected using self-administered questionnaires, there is a possibility of response bias, including social desirability bias, where respondents may overstate their compliance with best practices or underreport challenges in order to present their organization more favourably.

Lastly, the study focused solely on manufacturing firms within a single industrial zone, which may not fully capture the variability in warehousing practices across different regions or sectors in Malaysia. These limitations suggest that while the findings are valuable, they should be interpreted within the defined scope of the research.

### 5.6 Suggestion for Further Research

Given the limitations identified in this study, several avenues are recommended for future research to deepen and broaden the understanding of inventory accuracy in manufacturing warehousing.

First, future studies should consider employing a larger sample size across multiple industrial zones beyond Kulim Hi-Tech Park, such as Batu Kawan in Penang and Shah Alam and Subang industry hub in Selangor, to enhance the generalizability and representativeness of the findings. Expanding the geographical and industrial scope would allow for comparative analysis across different regions and sectors.

Second, researchers are encouraged to adopt a longitudinal research design to observe the long-term impact of system applications, storage design improvements, and material handling changes on warehouse operation accuracy over time. This would address the temporal limitations of cross-sectional studies and help establish causality more robustly.

Third, incorporating qualitative methods, such as in-depth interviews or case studies, could provide richer insights into the human, behavioural, and organizational dynamics affecting inventory practices, such as employee resistance to technology or training gaps.

Fourth, future research could explore the role of organizational culture, leadership support, or change management practices as moderating variables that influence the success of technology and process implementation in warehouse operations.

Lastly, given the rapid emergence of Industry 4.0 technologies, further research could investigate the impact of advanced automation, Internet of Things (IoT), and Artificial Intelligence (AI) on predictive inventory management and accuracy in real-time environments. These directions will not only complement the current findings but also contribute to developing a more holistic and future-ready framework for inventory control in manufacturing logistics.

**5.7 Conclusion**

This study investigates the influence of technology system, storage design, and material handling on warehouse operation accuracy within manufacturing company located in Kulim Hi-Tech Park. The research is motivated by the growing need for manufacturing firms to address stock inaccuracies, which can disrupt operations, escalate costs, and compromise supply chain reliability.

Grounded in the Resource-Based View (RBV) theory, the study developed a conceptual framework and tested three hypothesis using data collected from 30 manufacturing professionals. The results reveal that all three independent variables technology system, storage design, and material handling significantly and positively impact warehouse operation accuracy. Among these, technology emerged as the most influential factor, underscoring the pivotal role of digital tools such as Warehouse Management Systems (WMS), Radio Frequency Identification (RFID), and barcode scanning in ensuring precise inventory records.

The research contributes to management theory by validating the applicability of RBV in the context of warehousing operations within an emerging market. The empirical insights from Kulim Hi-Tech Park enrich existing literature on technology adoption and operational strategy, while offering practical implications for warehouse managers and policymakers. Additionally, the study aligns with national initiatives to digitize manufacturing processes under the National Policy on Industry 4.0 and supports regional competitiveness.

Despite its valuable contributions, the study acknowledges several limitations, including its geographic focus on a single industrial zone, a cross-sectional research design, and a limited scope of variables. These limitations present opportunities for future research to adopt longitudinal or mixed-method approaches, expand the geographic sample, and incorporate additional factors such as human resource capabilities, automation levels, and supplier integration.

In conclusion, the findings affirm that improving inventory accuracy requires a comprehensive strategy integrating advanced technologies, optimized storage design, and standardized material handling practices. For both academic researchers and industry practitioners, this study emphasizes the importance of aligning operational practices with digital transformation and strategic resource frameworks to achieve higher warehouse operation accuracy and supply chain excellence.

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## Appendix 1: Questionnaire

# ANALYSING ROLE OF TECHNOLOGY SYSTEM, STORAGE DESIGN AND MATERIAL HANDLING TO IMPROVE WAREHOUSE OPERATION ACCURACY

Dear Respondent,

I am currently pursuing a Master of Science in Logistics and Transportation Management and would greatly appreciate your participation in this survey. Your responses are crucial for the success of this research. The questionnaire will take approximately 5 minutes to complete. All responses will be kept strictly confidential and will be used exclusively for academic purposes. Should you have any questions regarding this study, please feel free to contact me using the details provided below. Thank you for your cooperation and the time you dedicate to complete this survey.



Manimaran Raman

School of Technology Management and Logistics (UUM)

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**Section 1: Demographic Information**

Please provide the following demographic information. Your responses will help us understand the diversity of our participants and analyse the data accurately.

1. Age:

- ◯ Below 25
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 and above

2. Job title:

- ◯ Warehouse Manager
- ◯ Warehouse Executive
- ◯ Warehouse Supervisor
- ◯ Warehouse Operator

3. Years of experience in warehousing:

- ◯ Less than a year
- ◯ 1 - 2 years
- ◯ 3 - 4 years
- ◯ 5 year and above

4. Education Level:

- ◯ High school or equivalent
- ◯ Diploma
- ◯ Bachelor's degree
- ◯ Master's degree

**Section 2: Analysing Role of Technology System, Storage Design and Material Handling to Improve Warehouse Operation Accuracy**

Instructions: Please indicate your level of agreement with each statement using the following scale:

| Strongly Disagree | Disagree | Slightly Disagree | Slightly Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

**Warehouse Operation Inaccuracy**

1. Inventory discrepancies between system records and actual stock are frequent in warehouse.

1 2 3 4 5 6

2. Inaccurate inventory records have caused delays in order fulfilment.

1 2 3 4 5 6

3. Team often discovers unexpected stockouts during picking operations.

1 2 3 4 5 6

4. Overstocking due to inaccurate forecasting or records is a common issue.

1 2 3 4 5 6

5. Manual inventory updates increase the likelihood of human error.

1 2 3 4 5 6

6. Periodic audits frequently reveal inconsistencies in stock levels.

1 2 3 4 5 6

7. Inventory errors often result in customer complaints or returns.

1 2 3 4 5 6

8. Inaccurate inventory has disrupted production scheduling.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

9. Cycle counting is effective in identifying warehouse operation inaccuracies.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

**Technology System**

1. We utilize a Warehouse Management System (WMS) to manage inventory operations.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

2. WMS provides real-time tracking of inventory across storage zones.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

3. The use of barcode systems improves stock location accuracy.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○



4. Integration between WMS and actual material enhances inventory visibility.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

5. Inventory discrepancies have reduced since adopting digital systems.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

6. Employees are trained yearly to use inventory software systems.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

7. Warehouse uses AI-driven analytics for inventory forecasting.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

8. System-generated alerts help identify potential inventory mismatches.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

9. Technology adoption has decreased reliance on manual stocktaking.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

**Storage Design**

1. Warehouse is designed to minimize congestion.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

2. Items are stored according to their picking frequency (ABC classification).

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

3. Space utilization is regularly assessed for improvement.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

4. Vertical storage systems are used to maximize space.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

5. Storage locations are clearly labelled and logically grouped.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

6. We conduct regular slotting reviews to optimize storage placement.

1 2 3 4 5 6

○ ○ ○ ○ ○ ○

7. Inventory damage is reduced due to organized storage infrastructure.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

8. The warehouse layout supports fast replenishment and retrieval.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

**Material Handling**

1. Warehouse uses latest material handling tools.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

2. Standard Operating Procedures (SOP) are enforced for all handling activities.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

3. Staff undergo yearly training on safe and efficient material handling.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

4. Handling practices reduce damage and misplacement of goods.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

5. Items are handled differently based on size, weight, and fragility.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

6. Conveyor systems are used to reduce manual movement of inventory.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

7. Material handling contributes significantly to overall inventory accuracy.

1 2 3 4 5 6
○ ○ ○ ○ ○ ○

**-End of Questions-**

Thank you for your time and cooperation in completing this questionnaire.