**Low-Carbon Warehousing Practices and Challenges: Insights from Emerging Country**

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**Abstract**

This study aims to identify the issues, challenges, practices, and research agenda of low-carbon warehousing that the manufacturing industry faces in the low-carbon era. The debate on managing low-carbon and sustainable warehousing has gained popularity. Managing energy consumption and carbon emission in the warehouse has become a critical success factor towards low-carbon practices. Semi-structured, in-person interviews and phone conversations were used to gather the information for this study. The convenience sampling technique was used. The results showed that the internal challenges, such as financial constraint, perceived knowledge in low-carbon warehouses, and the top management support were the frequently highlighted domains. The findings revealed that organisational support, international standards certification, local authorities, and customer pressure were key success factors in implementing low-carbon warehouse practices. The companies have taken proactive measures to address the best practice of low-carbon warehouses.

***Keywords:*** Low-Carbon Warehousing; Cross Case Analysis; Competitive Advantage; Decarbonisation; Energy Consumption

**Low-Carbon Warehousing Practices and Challenges: Insights from an Emerging Country**

## 1. Introduction

Managing operations sustainably in the manufacturing industry has progressed significantly over the years due to customer requirements. For example, the growing environmental concerns of consumers and government regulations have driven the emergence of a low-carbon supply chain (LCSC). In addition, manufacturing firms opt to achieve sustainable growth through LCSC practices to show their commitment to sustainable development goals (SDG) and a green economy. Manufacturing now adopts low-carbon practices in various supply chain (SC) stages, creating a greener environment for future generations and opening up multiple avenues for improvement (Rahman et al., 2020; Saputro & Rouyendegh, 2016; Zhang et al., 2022). With rising regulatory norms and customer awareness, low-carbon processes can maintain a sustainable competitive advantage and compete with their contenders (Ding et al., 2022; Wangsa et al., 2022). Therefore, sustainability practice needs commitment from the stakeholders and supply chain networks. This study argues that collaboration efforts in warehousing could improve supply chain efficiency and reduce warehousing costs.

Warehouse activities in the SC have become a significant source of emissions compared to other logistic activities. Their impact on global warming is undeniable because each logistic activity, including warehouses, contributes to the generation of greenhouse gas (GHG) emissions in the SC (Ali & Kaur, 2021; Bartolini et al., 2019; Goh, 2019; Modica et al., 2021; Popović et al., 2021). The increasing environmental concerns from customers and adherence to the government regulations in supporting SDG have forced firms to take proactive measures and focus on low-carbon processes, particularly in warehousing (Evangelista, 2014; Stekelorum et al., 2021; Tokat et al., 2021; Li et al., 2020). Moreover, low-carbon warehouse (LCW) is represented as a strategic means for the firms to underpin and aid in the explanation of a method to enhance achievement and gain a competitive edge (Chen et al., 2016; Kirchoff & Falasca, 2022; Zhang et al., 2022)**.** LCW is important to SC because the warehouse is previously considered as only a storeroom to preserve and shield products from extraneous effects. Now, warehouse has grown into a new paradigm, including environmental differentiation.

Due to this situation, firms now realize that the LCW practices are critical to create and sustain competitive advantages. Brand fidelity, increased stakeholder satisfaction, and flexible response towards market change are among the benefits that firms gain through the implementation of LCW (Agyabeng-Mensah et al., 2020a; Wangsa et al., 2022). On the contrary, the increasing pressure in cost and carbon emission reduction has led LCW to reposition the warehouse operations to be more environmentally friendly. Many studies have now incorporated LCW as one of the SC's environmentally friendly procedures (Rostamzadeh et al., 2015; Torabizadeh et al., 2020) despite the lack of a formal definition (Bartolini et al., 2019). Currently, a reduced energy consumption is the standard driver of the LCW strategy.

The LCW concept was derived from green and low-carbon SC management (Shaharudin et al., 2019). LCW refers to integrating and implementing a managerial concept and ecological of warehouse operations to reduce energy consumption, energy waste, energy cost, GHG emissions and protect the environment from warehouse operations (Bartolini et al., 2019; Li et al., 2020). LCW practices consist of warehouse operations conducted in a warehouse. It includes low carbon receiving, low carbon storage, low carbon material handling equipment, and low carbon shipping.

Low carbon receiving is associated with the energy usage at receiving facilities such as reduced travel times, faster product flow and better customer service; less product handling; inventory reductions; and, eventually, cheaper costs owing to the removal of the aforementioned tasks which in turn improve receiving process efficiently and also beneficial for the environment.

To successfully implement the LCW practices, companies need to identify and examine the practices, drivers and challenges that exist in the implementation process of LCW. LCW practices need to be examined in depth as LCW becomes increasingly important for the competitive success of the companies, especially in emerging countries like Malaysia due to stakeholders paying increasing attention towards the environmental aspects.

Previous studies found various challenges to LCW implementation. In addition, challenges in implementing LCW are divided into internal and external challenges, including technology, cost, knowledge, top management support and deficiency in the regulatory guidelines (Rahman et al., 2020; Tseng et al., 2019; Zhang et al., 2022). In another study, Menon et al. (2021) have identified 11 challenges and grouped them into three categories consisting of policy, human resources and technology in the Indian context. Meanwhile, Vishwakarma (2022) has identified and ranked challenges according to cause based and effect based challenges on greening the supply chain process including LCW. Different from the findings by Goh (2019), his study found that technology and governments were the main barriers for the case study companies to implement LCW practices.

With regards to the low-carbon process adoption, different countries or industry settings will drive towards the superior comprehension of unrevealed elements by previous studies. However, the results for each industry and country setting are different; it is difficult to be generalized (Fernando et al., 2022a). The barriers to LCW practices in the Malaysian context are not well explored. Most of the previous literature focused more on the barriers to green supply chain implementation from the perspective of manufacturing industries and logistics service providers instead of warehouse operations. This study is different from the other existing studies as it focused and discussed on the LCW practices and challenges from an emerging country perspective. Despite the increased academic interest in warehouse sustainability in the recent years, LCW and its impact on operational performance are still under-researched. Bartolini et al. (2019) indicated the expansive multi-disciplines of LCW research, consisting of warehouse sustainability indicators and guidelines, the effects of warehouse facilities on environment, and energy efficiency in warehousing.

The goal of this research was to investigate LCW practices and hurdles to implement in the manufacturing industry. The manufacturing industry involved in this study consisted of the aerospace, automotive, and electrical and electronic manufacturing industries. To achieve the research objectives, a qualitative research with cross-case analysis was chosen instead of the quantitative study because the former technique yields a distinctive depth of information and understanding which is difficult to obtain from the closed-question survey. Moreover, cross-case study can compare and contrast data. In this paper, we aimed to enrich the existing literature on the challenges of LCW implementation and practices in the Malaysian manufacturing industries.

The practical implication of this study is to assist practitioners in enabling LCW practices by developing an appropriate strategy. As previously mentioned, the literature gaps prompted us to perform this research in order to enhance LCW literature and practices. Inspired by the fact that warehouses are an increasingly significant contributor to carbon emissions in SC, the

followings are the research questions to be investigated:

- What are the current LCW practices in Malaysian manufacturing industries?
- Which issues and challenges have hampered the adoption of LCW practices in Malaysia's manufacturing industries?

The following is the structure. The introduction is in the first section of the study. The second section is the literature review. The third is the research methodology, followed by results and discussion in section four. Section five is the conclusion. Finally, section six is the limitations and suggestions for future research.

## 2. Literature Review

Like any other logistic activity, warehouses contribute to the production of GHG. The effects of warehouse activities on global warming are undoubtable. Hence, companies have begun to proactively implement environmental protection measures, such as LCW (Chen et al., 2016; Ding et al., 2022; Wangsa et al., 2022). Companies are paying more attention to warehouse economic and operational goals, and social and environmental issues; and changing the strategies to be more environmentally friendly due to the pressure from not only rules and regulations, but also investors, society, and industrial associations. Figure 1 shows the conceptual model of challenges in implementing LCW practices. LCW practices can be executed at all stages in the supply chain network, for example in the supply chain suppliers, manufacturers, distributors, logistics and transportation activities. All the aforementioned SC networks have their own warehouse activities. Therefore, LCW practices such as low-carbon receiving, low-carbon storage, low-carbon material handling, and low-carbon shipping can be implemented. Different SC network has different LCW challenges and these challenges can occur at each of the LCW practices. For example, LCW practices can be implemented in raw material supplier and manufacturing companies, distributors, logistics and transport service provider where there has a dedicated warehouse to store inventories such as raw materials, semi-finished goods, finished goods, maintenance, repair, and overhaul (MRO). However, what differentiates among these SC networks is the degree of implementation in LCW practices. For instance, some manufacturing companies have their own warehouse, while for distributors, the warehouse might be rented from logistics service provider therefore, not all LCW practices can be practiced. In the case of the distributor, even the degree of LCW practices is very limited, but the distributors can opt for the logistics service provider, which has very good sustainability of their logistics activities, including LCW practices. Further, this conceptual model elucidates that utilizing and integrating LCW practices as a part of companies' resources will improve competitiveness and operational excellence.

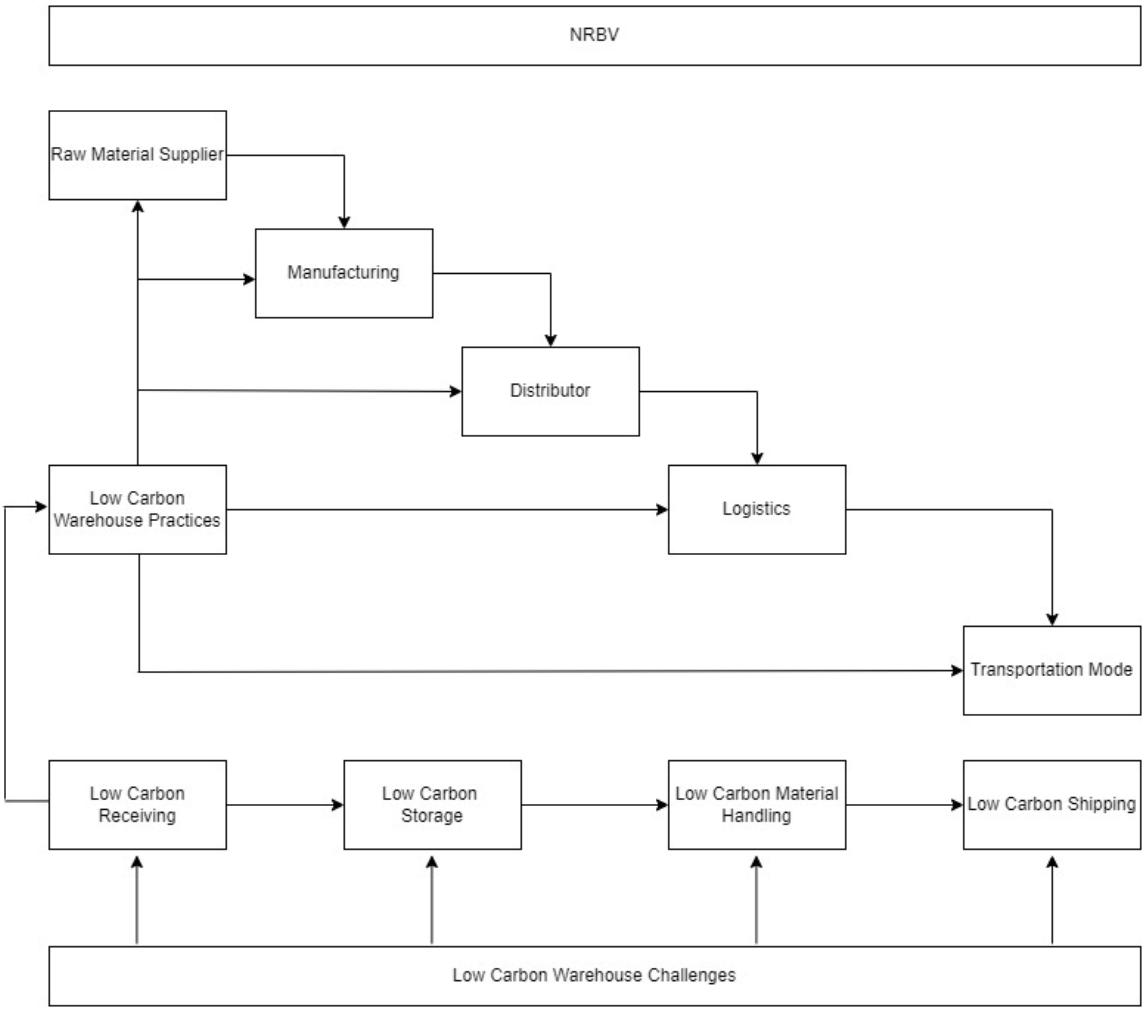


Figure 1: Conceptual model for the challenges in implementing LCW

## 2.1 Industrial Background

In the recent years, sustainable warehouse has gained popularity and attracted both academics and industries. Warehouses also experience remarkable changes with respect to environmental sustainability. Efficient use of energy in supporting warehouse operations can significantly reduce energy costs. The pre-emptive method, such as LCW practices, is executed in order to upsurge eco-friendly performance and accomplish competitive advantages (Junaid et al., 2022; Zhang et al., 2022). LCW practices have enormous benefits for manufacturers and companies (Rahman et al., 2020) in terms of not only environmental protection, but also survival and continued operations in today's highly competitive local and global business environment (Agyabeng-Mensah, et al., 2020b; Chen et al., 2016; Islam et al., 2021). Within logistic activities, warehouse is a temporary place to store a goods before reaching to the final customer. In warehouse operations, there are various activities that cause GHG emissions and at the same time, become a source of competitive advantage in meeting fluctuating customer demands (Ali

& Phan, 2022). LCW practices entail all warehouse operations, including receiving, storage, material handling, and shipping.

## 2.2 Definition of Low-Carbon Warehousing

A growing determination towards LCW and warehouse sustainability has steered new research with regards to the management concept, technologies and techniques in bringing down warehouse carbon emissions. In fact, some of the studies have included LCW practices as a sustainable process from a warehousing perspective (Kumar et al., 2020; Sherafati et al., 2020). However, the prescribed definition of LCW concept has not been produced so far. Based on previous studies, LCW practices are associated with reducing energy in terms of energy usage and energy cost through the energy-efficient warehouse processes (Bartolini et al., 2019; Kumar et al., 2021a). These not only help to reduce the GHG emissions caused by warehouse operations, but also lift the company's operational excellence. Besides that, companies can retain their competitive advantage in today's business environment. Previous studies have shown that increasing warehouse sustainability through low-carbon process requires each warehouse strategy to focus on reducing energy consumption and energy cost (Carli, et al., 2020; Li et al., 2020). In contrast, Sukjit et al. (2020) considered alternative energy and green building to be included in LCW. In addition, Sureeyatanapas et al. (2018) defined LCW as a process of decreasing the fuel and energy consumption in transportation and warehousing activities. Agyabeng-Mensah et al. (2020a) postulated that LCW practices could be accomplished by minimizing the energy resources and maximizing the warehouse space in order to abate cost, assure energy efficiency, and boost companies operational excellence through pollution-free energy which can reduce the costs with regards to environmental fines. Reviewing all the justifications from prior studies, in this paper, the term LCW can be defined as practices associated with reducing emissions of GHG, resource consumption, and energy cost of the warehouse operations.

## 2.3 Low-carbon Warehouse Practices

Topics on warehousing are broad and relevant with a variety of issues, such as warehouse design and operation (Bahr et al., 2022; Freis et al., 2016; Lewczuk & Kłodawski, 2021), warehouse operations planning and controlling (Carli et al., 2020b; Füchtenhans et al., 2021), warehouse performance measure (AlAlawin et al., 2022;Torabizadeh et al., 2019), warehouse automation (Andiappan et al., 2021; Chung, 2021; Li et al., 2021) and recently, smart warehouse (Zhen & Li, 2022). LCW practices in a warehouse process entail receiving, storage, material handling and shipping with the goal of reducing warehouse energy use, cost, and GHG emission. Energy usage at the receiving area is one of the elements that can be looked into in order to control the emission. Some of the manufacturers utilise the U-shaped warehouse layout where receiving and shipping areas are adjacent to each other. Energy usage at the receiving facilities includes product handling, product checking, and travel times. Energy usage is reduced by implementing LCW practices through utilising the technology, such as Radio Frequency Identification Devices, to trace and track the material flow starting from the receiving at the warehouse. The reduction in time and energy usage can lower the costs and improve customer service (Mahroof, 2019; Unhelkar et al., 2022). Moreover, the receiving process takes place in a loading bay. Hence, LCW can also be practised by putting in place energy-efficient and low-$CO_2$ emission ideas, including

building skin and building technology such as skylight, lighting, and ventilation system (Freis et al., 2016; Lewczuk & Kłodawski, 2021) . Short and dependable delivery lead times are critical in the warehouse due to the quickly changing consumer preferences, large product variety, tiny sizes, rapidly changing product mix, and rapidly changing customer demand (Boysen et al., 2019). In warehouses, travel time is crucial, and one of the critical performance metrics for assessing system efficiency as well as warehouse performance (Zhen & Li, 2022). Travel time shows how long it takes for things to be moved from one place to another.

Similarly, low-carbon storage, low-carbon material handling equipment, and low-carbon shipping are linked with the storage process, material handling equipment, and shipping process respectively. Low-carbon storage is a process for storage and retrieval involving strategies called storage assignment and retrieval system with the objective to reduce energy usage due to unproductive activities, including total travel time. Various processes in a warehouse, including storage assignment and retrieval system are logically interrelated. The use of appropriate storage policies, such as share storage policy leads to energy efficiency, reduces travel times, reduces cost and increases warehouse operational excellence (Li et al., 2020). Low-carbon storage increases the efficiency of the warehouse, including minimizing the travel distance of order picking, cost of picking, storage, and order picking time (Guo et al., 2021; Jiang et al., 2022; Rasmi et al., 2022; Wang et al., 2020)**.** Material handling equipment is the key component in supporting warehouse operations to directly impact warehouse performance, efficiency, and costs (Bartolini et al., 2019; Eko Saputro & Rouyendegh, 2016). According to Lewczuk et al. (2021), in a warehouse, energy consumption is commonly interrelated to the operation of material handling equipment. In this study, low-carbon material handling (LCMH) referred to the reduction of energy usage as a result of material handling activities (Carli et al., 2020a; Carli et al., 2020). Appropriate material handling systems and related energy consumption are considered while implementing LCMH which affects warehouse costs.

Although previous studies have not provided a specific definition of LCW practices, LCW practices can be defined as energy reduction practices in warehousing operations. In other words, LCW practices are a new way of conducting warehousing activities that shift from negatively impacting the environment to a more environmentally friendly process that reduces resource consumption and GHG emissions (Sellitto et al., 2019; Wahab et al., 2018). According to the findings of the aforementioned study, the operation management of the various process in a warehouse is interrelated. Therefore, this study was conducted to highlight the many benefits of LCW practices, such as increasing operational excellence of business (Tseng et al., 2019). To successfully adopt LCW, identifying the current low-carbon warehousing practices in the Malaysian manufacturing industry is crucial.

### 2.4 Challenges Implementing Low-carbon Warehouse

Given that LCW practices are still new, every manufacturing industry faces various challenges in adopting them. The pressure from outside parties, such as governments, customers, and non-governmental organisations towards the manufacturing industry to expedite LCW practices is among the challenges faced by the companies. However, successfully adopting LCW practices is frequently challenging, mainly when companies have limited resources and capabilities. According to Goh (2019), a few challenges for third-party logistics (3PL) to execute LCW practices include cost, complexity, communication, knowledge (or ability), government, supplier, customer

and technology challenges. These findings are aligned with the results of other scholars in the literature, with the challenges being divided into a few groups: financial, technology, human resources, and policy (Menon & Ravi, 2021).

### 2.4.1 Cost-related Challenges

Reducing costs is a crucial driver and determinant of whether low-carbon practices or processes are adopted. Previous studies have found that high costs for waste disposal processes, packaging that is ecologically friendly, and the use of low-carbon technology are the reasons why companies refrain from pursuing LCW practices (Centobelli et al., 2017; Evangelista et al., 2017; Islam et al., 2021; Mathiyazhagan et al., 2013; Richnák & Gubová, 2021). Moreover, high investment costs and lower return on investment in material handling, for example, are among the factors that postpone LCW practices. These factors are supported by previous findings that investment in energy efficiency is often the cause of additional costs for companies rather than providing a competitive advantage between contenders (Evangelista et al., 2017; Fernando et al., 2022b;Fernando et al., 2021). This situation is relevant for companies that are pressured to increase profits without considering the consequences of their operations on the environment. Consequently, the high cost of implementation makes it difficult for organisations to adopt LCW practices.

### 2.4.2 Complexity-related Challenges

According to previous literature reviews, implementing LCW practices increases an organisation's complexity (Abbasi & Nilsson, 2016; Centobelli et al., 2017; Evangelista et al., 2017; Goh, 2019) For example, the implementation challenges require time and effort to disseminate low-carbon practices and become a new culture in an organisation. On the other hand, the impact on administrative action is needed in monitoring and measuring the level of carbon footprint. Besides that, the lack of technical expertise and human resources in green initiatives is a challenge to LCW practices (Menon & Ravi, 2021). Thus, it makes transforming towards low-carbon process to be unfavourable for the companies, especially for small and medium enterprises (SMEs). For them introducing a new low-carbon process is adding another complexity in term of reporting for instance.

### 2.4.3 Knowledge or Capability-related Challenges

Lack of environmental knowledge, education or training, and expertise on LCW practices have delayed and affected the implementation process (Kaur et al., 2018; Menon et al., 2021; Yassin et al., 2021). The lack of a standard definition of the low-carbon process is also a critical challenge in implementing LCW practices. Modernisation and innovation are essential components of LCW practices. The innovative approach is to achieve the objectives of low-carbon practices. Therefore, companies need a skilled and experienced workforce when implementing new systems, such as LCW (Menon & Ravi, 2021b). Lack of capacity in LCW practices is frequently expressed as a gap, especially in technical knowledge, skills, and professional advice, which is a concern in SMEs (Mathiyazhagan et al., 2013) and developing countries (Tumpa et al., 2019; Zhu & Geng, 2013). As a result, it is impossible to improve free or low-pollution processes due to the lack of knowledge.

### 2.4.4 Government-related Challenges

Other studies have recognised the institutional pressure from legislative and regulatory compliance as a potential driver of implementation (Goh, 2019). However, this driver can also impede if there is no coherence to address non-compliance, such as an insufficient direction from regulatory bodies and vigorous legislation (Menon & Ravi, 2021b). Organizations are persuaded to implement LCW practises through regulation and advice in technical support, incentives, and law (Tumpa et al., 2019). The government should emphasise on inducement plans to inspire manufacturers to embrace LCW practices instead of enforcing laws or regulations. Other challenges include differences in regulations between countries and industries (Majumdar & Sinha, 2019).

### 2.4.5 Supplier-related Challenges

Building external partners or collaborating with suppliers is vital to support LCW practices. Majumdar et al. (2019) reported that finding external partners or suppliers to cooperate with and work together on green initiatives was challenging. This challenge is due to an absence of belief and environmental involvement amongst SC partners, a scarcity of green supply, supplier reward system issues, and suppliers' reluctance to support one another in the SC. According to Goh (2019), difficulties arise when sharing sensitive information or technology related to sustainable practices that serve as a basis of gaining a competitive edge. Meanwhile, Mathiyazhagan et al. (2013) indicated that the lack of knowledge between suppliers was a key challenge in implementing green practices.

### 2.4.6 Technology-related Challenges

Implementing LCW is hampered by the lack of appropriate technologies, processes, and effective environmental measures (Majumdar & Sinha, 2019; Menon & Ravi, 2021). The lack of technologies in an organisation refers to utilising resources optimally and effectively through waste management, recycling, and reusing. Furthermore, Menon et al. (2021) emphasised that technology was very convenient in redesigning, information flow, and process improvement. New technological capabilities in green innovation and LCW know-how are closely linked to a company's financial and human resources.

### 2.4.7 Involvement and Support

Previous studies' findings discussed the challenges of top management involvement and support. Among these are the dearth of top management reinforcement in incorporating sustainable execution into the company's mission and vision (Yassin et al., 2021), the lack of commitment to corporate social responsibility (CSR), and the absence of environmental goals (Majumdar & Sinha, 2019)**.**

There are challenges that restrict company policies towards low-carbon processes, such as failing to ensure the process' safe environmental impact. Therefore, the top management commitment to support, formulate company goals, and allocate resources to green initiatives is crucial. Besides that, top management spearheads the implementation of company policies on sustainability throughout their SC (Menon & Ravi, 2021b). Gupta et al. (2020) discovered the inability of various departments to integrate and coordinate their goals and work towards a

sustainable plan. As a result, LCW practices are unable to be executed successfully in the absence of integration or synchronization across units.

## 3. Methodology

### *3.1 Research Design*

The goal of this study was to understand the contemporary practices of LCW and the challenges that Malaysian manufacturing industries face in adopting LCW. The implementation of LCW is still in its infancy, necessitating a comprehensive and in-depth investigation to understand the challenges. Therefore, a qualitative research with cross-case analysis studies was chosen in this study based on the following reasons:

a) LCW is a relatively new and widespread practice. Selecting LCW practices becomes a complex process, with various issues and challenges confronting companies. It is best to employ qualitative research methodologies (case studies) to comprehend the situation in such a dynamic environment.
b) In-person meetings with respondents can aid in understanding the information on various qualitative topics, including the reasons for implementing LCW practices, processes, discussions, and feedback.
c) Multiple case studies can provide more robust insights, resulting in higher external reliability and validity. Cases are viewed and studied separately in conjunction with other cases (within-case and cross-case analyses) to provide contrastive analysis and richer details and insights into the research issues.

A cross-case analysis is the most preferred approach for this study since the evidence from multiple case studies is more convincing and robust. The case study urged individuals to seek mutual and LCW practices and challenges. Supporting evidence can be gathered through cross-case studies until saturation is achieved.

### *3.2 Sampling Design*

This study collected data using a convenience sampling technique within the identified target groups. The collected data is analysed to understand the practices and challenges of LCW. This case study's scope and nature are precise, involving the practices and challenges of LCW in the company. Therefore, the employees who participated in the company's strategies were chosen for the interview as shown in Table 2. Meanwhile, the interview questions were separated into five categories as shown in Table 1.

Table 1: The different parts of interview questions

| Part | Description |
|---|---|
| A | Demographic of the respondents |
| B | Challenges in implementing LCW |
| C | Current practices of LCW |
| D | Organisational support in LCW |
| E | External factors in implementing LCW |

### *3.3 Data Collection*

This case study concentrated on the practices and challenges of LCW in three companies: A, B, and C. The respondents for this interview came from the top management, and their perspectives on operational and managerial issues were directly queried. Table 2 provides detailed information on the three companies being interviewed. The first point of contact was with the head of the SC department, and a formal interview was successfully scheduled. On average, 30 to 50 minutes of the meeting were very fruitful in term of information provision. However, because of the limited time and the company was amid a busy season, it was agreed that follow-up interviews with respondents would be conducted via phone calls if additional information was required.

Table 2: Description of the three case-studies

| Cases | Date of Creation | Field | Position |
|---|---|---|---|
| Company A | 1990 | Aerospace | Interview 1: SC Manager<br>Interview 2: Warehouse Manager |
| Company B | 1988 | Electrical and Electronics | Interview 3: Warehouse Manager<br>Interview 4: Health and Safety Manager |
| Company C | 1994 | Automotive | Interview 5: Logistics Manager<br>Interview 6: Health and Safety Manager |

*3.4 Procedure*

The respondents were contacted, and invitation letters were sent via email with an attached PDF file. The attachment was a letter signed by the Deputy Dean of Research and Postgraduate Studies on university letterhead, explaining the significance of participation in the study and part of the university research project. The data collection guide was sent to the respondents to become acquainted with the subject ahead of time. The data was gathered through pre-scheduled interviews, either in person at the company or in some cases, over the phone. Human Resources Managers from the companies provided ethical approval for the study. Before the interview, the person in charge was informed about the survey. The data was collected over two months, beginning in June 2019 and ending in July 2019, and the interviews were conducted during workdays. The interview procedure was as follows: first, the researchers informed the interviewees that the Human Resource Manager had granted permission for the interview to take place. The researchers then explained the study's purpose.

To encourage openness of response, the names of the firms were kept confidential (case firms are denoted by letters ranging from A to C). The respondents are more likely to provide the necessary information if they are anonymous. If necessary, the order of the questions was altered, or additional questions were asked. Before the interview, each company's website was thoroughly examined, and information about the company’s general activities focusing on sustainability, and reports were gathered. The data was collected and recorded in an organized and systematized file folder and computer files. Each interview lasted between 30 and 50 minutes on average, and was recorded using an electronic recorder. The interviews were later transcribed

to be analysed. Internal presentations, company reports, journals, websites and portals were all included in the case study database to provide a complete picture of the situation (Yin, 2018).

### *3.5 Case Study Selection*

The initial group of companies was chosen based on the following specific criteria:

(a) Include companies with a variety of business types. There are various green initiatives in various industries (Evangelista, 2014). For this reason, the selection process included companies from the aerospace, automotive, and electric and electronic sectors and their warehousing.
(b) Include companies with varying environmental sustainability emphases. This data was gathered from various secondary sources, including firm corporate websites, annual reports, and articles in industry magazines.
(c) Include companies of various sizes. Rendering to Kudla and Klaas-Wissing (2012), the size of a company may influence its attitudes toward green initiatives.
(d) Include companies that have previously been involved in research projects and have had previous contact and collaborations. It was assumed that this would make the contract with managers and access to company information much more accessible.

Ebneyamini et al. (2018) discussed that the basic principle of selecting any case strategy was to select information-rich cases. Therefore, criteria b and d had the most significant influence on the selection decision. In this case study, the data was gathered through face-to-face interviews and phone calls.

### *3.6 Data Analysis*

The information gathered through conversations was recorded and transcribed. There were four main stages involved in data analysis (see Figure 2). In Stage 1, the data translation process began by translating information from the respondents into English. In Stage 2, all industry terminology and language were also translated. After that, in Stage 3, the information from the interviewees was rearranged accordingly before starting the analysis of response in Stage 4. Finally, all the transcribed interviews were copied into an Excel spreadsheet.

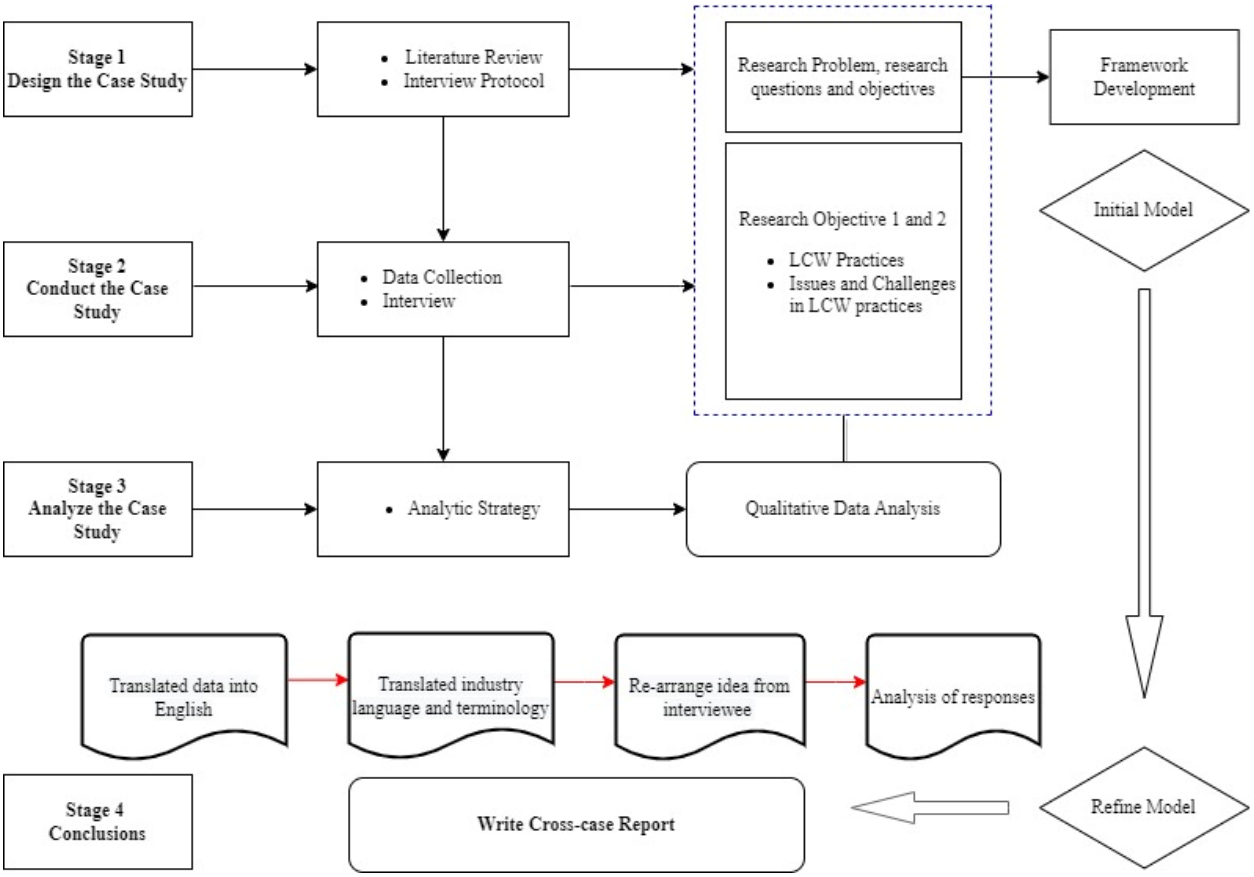

Figure 2: The transcript analysis process

## 4. **Results and discussion**

The interviews were conducted semi-formally with open-ended questions. The responses to the questions about LCW practices in the workplace were analysed and presented. The results were tabulated and classified accordingly. Table 3 shows the company profiles of the case study companies. Meanwhile, Table 4 depicts the summary output for challenges in implementing LCW in the Malaysian manufacturing industry. Table 5 summarises the current practices of LCW in the Malaysian manufacturing industry while Table 6 presents the summary output of organisational support. Finally, Table 7 summarises the output for external environments in the Malaysian manufacturing industry when implementing LCW.

Table 3: The profile of the case study companies

| | | A | B | C |
|---|---|---|---|---|
| Warehouse Facilities | Private warehouse | • | • | • |
| | Public warehouse | | | |
| Company Size (employees) | | | | |
| | Micro (less than 100) | | | |
| | Small (100 - 250) | | | |
| | Medium (251- 500) | | | • |
| | Large (>501) | • | • | |
| Geographical Reach/Market | Local | • | • | • |
| | International | • | • | • |
| International Standards Certification | ISO 14001 (Environmental Management) | • | • | • |
| | ISO 9001 (Quality Management System) | • | • | • |
| | ISO 50001 (Energy Management) | | | |
| | Others | • | • | |
| Company Listed in Malaysian Stock Exchange | Yes | • | | |
| | No | | • | • |

From Table 3, company A, B, and C own their private warehouse. These ownership elements showed that each company had direct control over their warehouse compared to a public warehouse. Therefore, there are no obstacles that the companies must overcome when embarking on or initiating LCW practices. While company A and B were large corporations with more than 500 employees, company C was a medium-sized industry with fewer than 500 staff members.

In term of geographical reach, all three companies were local and international, meaning that their customers and suppliers were either local or international. Reaching local or global markets necessitated compliance with specific rules and regulations imposed by authorities. International standard certifications, such as ISO 14001 and ISO 9001, have been awarded to all three companies. In contrast, their customers required additional international standards certification for companies A and B, such as AS9100 (QMS for the aeronautical industry) and ISO13485 (QMS for medical devices), respectively.

Table 4: The summary output for challenges in implementing LCW

| Respondents | Remarks |
|---|---|
| A | There are several primary challenges in implementing LCW. Financial constraints, knowledge of LCW, support from top management, and struggle to sustain the green initiative are among the challenges. |
| B | Budget constraint, top management awareness, and low carbon knowledge are the main challenges. |
| C | The main challenges in implementing LCW is cost, knowledge, and awareness. Apart from these, top management support and sustaining the green implementation have become the issues, in addition to limited resources such as old buildings and changes in small product design. |

The summary output for challenges in implementing LCW in the Malaysian manufacturing industry is shown in Table 4. The main challenges for implementing LCW practices, according to all respondents, were costs, knowledge, awareness, and top management support. Factors such as high initial cost caused certain companies to delay their low-carbon initiatives. On the other hand, companies under intense profit pressure perceived LCW practices as an extra cost rather than a competitive advantage that distinguished their business from competitors. The companies' main challenge when implementing an LCW practice was the cost, with respondents from three companies highlighting cost elements frequently. This finding was supported by previous scholars (Kumar et al., 2021b; Aravindaraj & Chinna, 2022), who argued that cost was the main challenge faced by organizations who wanted to pursue green initiatives, especially from small and medium enterprises. Company A was in the expansion stage; hence, any investment made was focused on Capital Expenses (CAPEX), such as buying new machinery and constructing a new building. Any investment in LCW practices receives top management approval promptly. Therefore, company A's warehouse department was only looking for processes and equipment, and quickly converted with a short payback period. On the contrary, company A's management actively encouraged its employees to participate in continuous improvement (CI) programs. Every department was welcomed to make any amendments that resulted in process improvement, cost savings, increased energy efficiency, and ultimately, increased operational excellence.

Furthermore, company A was a publicly listed company, and the company was required to report on sustainability initiatives, including LCW, to the bourse. Apart from cost and top management support, company A's other challenges in implementing an LCW is knowledge. Limited or lack of knowledge regarding LCW practices and the outcomes of implementing such low-carbon process towards the company’s operational excellence have made these initiatives less critical. The respondents required unique or dedicated departments or people who could focus solely on the warehouse instead of the entire company. They needed a subject matter expert (SME) who could be creative and innovative in bringing LCW practices. This finding was supported by previous studies from Vishwakarma (2022), which categorized the challenges

pertaining to low-carbon process implementation based on their operating implications such as cost, management commitment, and knowledge. Another challenge that company A faced was sustaining the low-carbon process. Maintaining and embedding a new strategy, particularly in LCW practices, were difficult for them. As opposed to company B, warehouses were the primary impediment to adopting low-carbon practices. According to the respondent, obtaining approval from the top management for paperwork prepared for LCW practices without a directive from their parent company would be difficult. Therefore, every cost associated with adopting an LCW should be included in the annual budget, making it easier to obtain approval in the future.

In contrast, the top management awareness was one of the challenges that company B and C faced when implementing LCW practices. Referring to the respondent from company B, the top management was aware of the importance of expediting the approval of working papers related to LCW practices. The cost of implementing an LCW practice was also a significant constraint for company C. Company C's price included the use of some material handling equipment that supported LCW but was unsuitable for their daily processes. For example, the limitations of using a battery forklift. In other words, forklift batteries were only ideal for lifting light goods and unsuitable for lifting heavy items. Company C's other significant challenges, like companies A and B, were employee knowledge and awareness, and top management support. Besides that, the sustainability of the LCW process also became a challenge. Apart from this, the respondent from company C mentioned that little could be done, especially in the warehouse, because the building was old and had a little product design change.

The research findings from the three companies can be concluded that the main challenges faced in implementing LCW practices were cost, knowledge, awareness and top management support. To overcome the challenges, collaborations between the top management and warehouse workers in greening the warehouse process are required. They need cooperation to overcome the LCW challenges, for example from the top management who need to support LCW activities. On the other hand, some LCW activities involve other internal departments. Therefore, cooperation between parties is important in ensuring the success of LCW. Therefore, to overcome or reduce the challenges of practicing low-carbon warehouse operations, collaborative efforts between management and employees should be established to ensure the success of this LCW practice. With regards to the knowledge and awareness of LCW practices, organizing more awareness programs that discuss the benefits and opportunities of low-carbon processes including LCW practices are among the suggestions that can overcome the challenges. Other than that, spreading low-carbon ideologies across departments, instead of through the usually designated departments can also be part of the initiatives to overcome the challenges of implementing LCW practices.

Table 5: The summary output for the current practice of LCW

| Respondents | Remarks |
|---|---|
| A | The current LCW practices in the company are optimising warehouse space and material handling equipment. Energy management is also practiced in the warehouse area and the company. |
| B | Warehouse space is utilised where goods are stored according to product category. Energy-saving equipment such as light emitting diode (LED) lamp, inverted air conditioner, and solar panel project will also be included. |
| C | The current practices on low-carbon processes focus on warehousing and involve other departments. The company also focuses on energy and waste management, green packaging, storage, logistics, and shipping. |

Table 5 shows the current LCW practices in the three companies. Overall, LCW was actively practiced by the three companies. Even though the LCW process was not entirely used, only a particular method was involved in the low-carbon process. Respondent A stated that the company's instruction was to optimise warehouse space and the use of material handling. Moreover, energy management was actively practised in the warehouse operations and whole company, which resulted in energy savings. Respondent A stated, *"In our effort to reduce carbon emissions through energy management, the company has invested substantially in transforming 100% to LED lightings, changing LPG gas to nitrogen, and recently implementing 8 MW Solar PV in reducing electricity usage".* If what has been disclosed is accurate, company A will effectively reduce its electricity consumption and costs.

Meanwhile, respondent B utilised the warehouse space by arranging products by category. The goods in their warehouse were arranged following the movement of that product. Products with a high or fast movement were located near the loading bay, whereas slow-moving products were far from the loading bay. According to them, this arrangement aimed to increase order picking efficiency, thus warehouse operations efficiency. Apart from that, company B has begun implementing energy management in its warehouse operations. Using an inverted air conditioner, solar panel project, and replacing the fluorescent lamps with LED lights were to reduce energy consumption. This initiative further reinforces company B's commitment to reduce its environmental footprint. As a result, company B reduces its electricity consumption.

Finally, according to respondent C, the company has implemented the low-carbon process in the warehouse department, which involves the entire company. Company C progressively measured its electricity usage and computed its carbon footprint. It is worth mentioning that reducing carbon footprint is their corporate direction, calculated monthly. Energy management policies are being practised at the loading bay area to reduce pollution, with signage of "*Engines Must Be Turned off during Loading and Unloading".*

Table 6: The summary output of organisational support

| Respondents | Remarks |
|---|---|
| A | The duties of senior management in supporting the execution of LCW are crucial because it involves cost, especially in the early stage. Furthermore, the green initiative is a direction from top management. |
| B | Top management's support is crucial, especially when it comes to budget approval for low-carbon activities. |
| C | Top management support is critical to ensure that the project or initiative is successful and sustainable. Reduction of carbon footprint is one of the company's corporate drives. |

Table 6 shows the organisational support for LCW practices. All respondents agreed that corporate support was crucial in implementing LCW practices. Support is vital during the implementation stage and in sustaining low-carbon activities. Organisational support includes a clear direction from the top management regarding LCW practices. For instance, a respondent from company A stated, "*Our company has established our Sustainability Roadmap encompassing safety & health, energy management, waste management, human capital development, corporate responsibility, and SC management".* It has been demonstrated that management support and commitment to sustainability, such as LCW practices, are critical to success.

Meanwhile, Company B required the top management approval for budget approval. It is critical to expedite paperwork approval to avoid delays in the improvement process. Company B also received the top management support. Each department's improvement process was rewarded with employee incentives. Indirectly, this allowed employees to develop thoughtful ideas towards LCW practices. Similarly, company C, like company A and B, has the same argument about management support for LCW adoption. Company C believes that the success of a low-carbon practice or any green practice, is due to the top management's strong support. Furthermore, reducing carbon emissions intensity by 45% by 2030 was one of the directions of company C that aligned with Malaysia's commitment towards the green economy.

Table 7: The summary output of external factors in implementing LCW in the Malaysian manufacturing industry

| Respondents | Remarks |
|---|---|
| A | An external factor such as ISO 14001 assisted in implementing an LCW. This international standard is critical in guiding the handling of hazardous materials. Local authorities and customer pressure are two external factors contributing to LCW practices. |

| | |
|---|---|
| B | ISO 14001 is crucial in guiding the company to practice an LCW. Customer requirements for green technology have forced the company to embark on LCW activities. The company also participates in the Green Technology Financial Scheme. |
| C | International standard certificates such as ISO 14000, OSHA, and ISO 19000 are essential because they are a business and customer requirement. The company should get this international standard certificate to remain competitive. Other international standard certificates for different industries are AS 9100, IATF 16949, and ISO 13485. |

Finally, Table 7 shows the external determinants of the implementation of LCW practices in Malaysian manufacturing industry. According to the respondent from company A, a few external factors facilitate the companies to embark on LCW practices. International standard certificates, such as environmental management systems (ISO 14001), have established the conditions or rules that a company must follow before being awarded the certificate. This environmental management system certificate is vital to the company to provide practical tools to manage their environmental responsibilities, including waste materials, hazardous material management, and storage.

Moreover, company A is one of Malaysia's leading manufacturers of aircraft components. Therefore, the pressures from local authorities and customers are two external factors leading to LCW practices. Company A acts as an aerospace industry player in this highly regulated industry. Hence, it is required to align with the original equipment manufacturer (OEM), i.e., Airbus or Boeing, towards reducing carbon emissions by implementing various green initiatives.

Meanwhile, company B stated that international standard certification was essential in guiding LCW practices. References and guidelines in the environmental management system covered various management aspects such as safety and health, waste, energy, and SC management. Additionally, customer needs for a greener process drove company B to adopt LCW. To support the Malaysian government's efforts to reduce carbon emissions by 45% by 2030, company B has also participated in the Green Technology Financial Scheme. According to the respondent, the company has obtained a government grant to begin installing solar panels.

Similarly, the respondent of company C agreed on the importance of the international certificate in assisting their company in adopting LCW as it could help by providing guidelines. This certificate was one of the business and customer requirements for company C. International certifications such as ISO 14000, OSHA, and ISO 19000 are crucial to compete in today's market. This situation is supported by the fact that company C produced various goods for niche industries such as medicine, aerospace, and electrical and electronic devices. They believed that various international standard certifications, such as AS9100, IATF16949, and ISO13485, must be met.

## 5. Theoretical Implications

There are several theoretical implications derived from this study. First, it contributes to the

knowledge of LCW in the context of emerging countries. Although there are previous studies debating the green warehouse, only a few studies are conducted in the context of emerging countries specifically in the Malaysian context (Fernando et al., 2022c). Furthermore, the results attained from developed countries may not be suitable to be practised by the firms from developing countries. Consequently, this study has made an addendum to the paucity in the sphere of green warehouses by investigating the LCW practices and challenges from the emerging country's point of view. Second, this study contributes to reinforcing the theory of Natural Resource-Based View (NRBV) where the findings from this study elucidate that utilizing and integrating LCW practices as a part of companies' resources will improve competitiveness and operational excellence. We argue that the LCW practices have guided the companies to establish pollution prevention by reducing gas emissions and pollution in each warehousing operation. Furthermore, utilising company resources to reduce the environmental impact for companies' survival and competitiveness. Lastly, companies that adopted LCW practices can support sustainable development that comprises social and economic concerns industries. This study examines the new paradigm in greening warehouse operations through LCW practices. Concentrating on LCW practices to reduce the environmental impact of the warehouse can enhance warehouse operational excellence significantly. LCW practices could reduce energy costs and energy usage by redesigning a warehouse process towards a zero or low-carbon warehouse process. Using or switching from fossil fuel to renewable energy is among the processes or operations that are often being practised to remain competitive.

## 6. Managerial Implication

In terms of managerial contributions, this study helps manufacturing companies to have a clear picture of what is constituted in LCW practices and to promote LCW adoption in warehouse operations. Manufacturing firms can use the framework proposed by this study to espouse sustainable warehouse practices, such as LCW practices while at the same time, enhancing warehouse operational excellence. This is because, the findings of challenges in LCW implementation inspire managers to recognize the significant challenges that might affect companies from venturing into the low-carbon process. In addition, the findings from this study help managers to attract more foreign investors to invest in developing country due to their serious commitment in promoting sustainable development goals. Moreover, the findings from this study also help managers show their commitments to support and achieve sustainable development goals and meet social, economic and environmental demands simultaneously.

## 7. Conclusion

Green initiatives such as LCW are now gaining traction, and industries are focusing more on them. Malaysian manufacturing industries are expanding, and companies are pushing for a sustainable SC that considers environmental and social impacts. This study analysed and categorised LCW practises and challenges to comprehend their impact on LCW implementation in the Malaysian manufacturing industry. The main findings for LCW practices used in the manufacturing industry were to reduce energy usage or consumption in the warehouse area.

From the findings, LCW practices included implementing energy efficiency at warehouse operations through utilizing warehouse space and material handling equipment. Warehouse space and material handling are interconnected process which incurs additional costs and adversely affects the environment, such as GHG emission if not managed properly. Likewise, energy management has been introduced in the warehouse, resulting in energy savings and improving operational excellence. The company has taken actions to reduce energy consumption such as switching to LED lighting from conventional lighting and minimising forklift movement through storage assignment. The organisation has also taken a more proactive stance by embarking on solar energy. Solar panels reduce reliance on electricity, hence lowering electricity consumption. Apart from that, the Government of Malaysia provides financial assistance and tax relief for installing solar panels, known as the Solar Renewable Energy Project. However, implementing any sustainable or green activity, such as LCW, is challenging as greening the warehouse operations involves receiving, storage, material handling, and shipping activities.

This study was also conducted to identify the main barriers in the LCW implementation among Malaysian manufacturing industries. It was found that cost constraint, lack of knowledge, awareness and top management support on LCW practices and implementation were among barriers often faced by the practitioners. Similar discussion was presented by Goh (2019), Islam et al. (2021), and Wahab (2021): they argued that the challenges in implementing sustainable or low-carbon warehouse were divided into technological, cultural, and social aspect, with economic challenges being the most prominent and requiring immediate attention by organisations and policymakers. Several strategies, such as investing in cutting-edge technology and motivating employees to think outside the box and to adopt sustainable practices, can help overcome these challenges. Furthermore, regulatory support in terms of favourable policies and slight tax slabs for organisations that embrace environmentally friendly and sustainable practices is critical. Additionally, assistance includes access to infrastructure and technologies available in other advanced countries and training with the purpose to adapt a sustainably minded culture.

This study has some limitations. Future studies and empirical investigations would be able to address these limits. Theoretically, the challenges in this study were identified by utilising an existing literature analysis and the opinions of industry managers. An empirical validation and a more scientific approach are needed, particularly in Malaysia's other industries. The current study only gathered data from Malaysian manufacturers. Adding other sectors, such as logistics service providers, would make the results robust due to the scientific evaluation. Including wider topics of organisations is required to determine the extent of these practices and challenges that prevent manufacturers from implementing LCW practices. More than what was found in this study could be identified. Hence, all obstacles to LCW implementation are necessary to be identified and treated.

Exploratory research was used in this study, including three companies and 20 interviews gathered from a methodological standpoint. The managers who took part in this study were volunteers, and they might have demonstrated a higher level of knowledge and understanding in greening their warehouse process. Nonetheless, a larger sample size would improve the results by providing more perspectives. This study's methodology and framework were used in several sectors, such as chemical, leather, pharmaceutical, and automobile industries, to evaluate LCW practices together with the challenges. Therefore, possible strategies to alleviate the challenges are implemented. Further research, particularly in the area of LCW is needed especially in the

country's current economic, social, and technological context.

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Data availability: Not Applicable

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