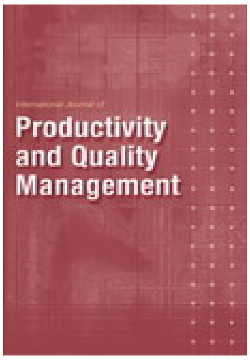

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Improving warehouse capacity, productivity and sustainability

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Improving warehouse capacity, productivity and sustainability

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Abstract: This study aims to examine warehouse capacity utilisation, productivity and sustainability. The methods used in this study are the symptom versus problems approach (SVP), mathematical computation and simulation. By using SVP, it is confirmed that space utilisation is the source of warehouse productivity. The rate of the current warehouse is calculated using the Frazelle model, and it proves that the existing warehouse layout is under-utilised. Improvements and storage utilisation rates will then be calculated. The simulation method runs the improved warehouse layout with its main activities using the Anylogic software. With simulation, the new design layout would be adequately visualised, including the main activities and areas of operating with its throughput. Our study has suggested that complying with sustainability features and guiding low-carbon warehouse principles will assist the company one step further compared to competitors.

Keywords: productivity; symptom versus problem; SVP; frazelle model; anylogic software; warehouse; sustainability.

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1 Introduction

Logistics has a salient aspect in daily operations but impacts productivity, sustainability and corporate financial performance. One of the logistic functions is to generate data on the accurate inventory and control the cost. The inventory accounting systems can assist the logistics manager in making business decisions on the management control mechanism. In addition, accounting information systems can give critical information on the current business position in the industry, especially to plan and manage the flow of storage products under multiple supply chain networks. Accounting in logistics and supply chain management is critical to maintaining lean operation, especially when the global company is involved in offshoring activities for cost-efficient operations. Da Silva Stefano et al. (2021) argued that throughput accounting was a helpful method to optimise the operational aspects of pricing, sourcing, and inventory decisions.

The company's ability to manage logistics operations competently can reduce unnecessary energy consumption and operational costs and increase productivity. To survive in the industry, a company need to allocate sufficient resources to support logistics operations. The warehouse is a planned space for efficient storage and handling the goods and materials (Qiu et al., 2022). Therefore, warehousing is considered a critical element in logistics and supply chain management (Zhen and Li, 2022). The warehouse management can reduce costs when the company manages and arranges the layout and capacity. If the company cannot handle it, they need to rent the warehouse space and bore the cost. Therefore, the warehouse requires a spacious avenue and management to accommodate workstations and inventory. But then, the area is seemed to diminish on its own after years of operating. Fernando et al. (2020) argued that managing a warehouse is challenging when it involves automation within global sourcing and networks.

The warehouse has played an essential role in improving business effectiveness and performance. Currently, the warehouse is focused on improving capacity and productivity and complying with sustainability requirements. Some companies prefer to rent the warehouse space instead of establishing the new one. According to Mashud et al. (2021), warehouse space rent does not always negatively impact business performance. It can be more efficient compared to building the new larger warehouse. The managers should be aware of the need and priorities. Salhieh and Alswaer (2021) have developed the warehouse maturity model. It will help the warehouse managers to improve warehouse practices, techniques and performance. Fernando et al. (2022a) argued that modern businesses nowadays demand more green-oriented production activities that comply with restructuring architecture and recycling. The warehouse management has contributed to the business's sustainability. The proper design of warehouse management systems can improve the arrangement of raw materials, work in process and final products. In the same vein, Ali et al. (2022) highlighted that warehouse management design for reducing operational costs and carbon footprint can deliver favourable environmental sustainability results. Karim et al. (2018) show that the top three reasons for warehouse failure are labour productivity, warehouse space utilisation, and inventory space utilisation.

Furthermore, it shows that warehouse daily operations are affected when workers have limited working areas as their movement to conduct the activities are limited (Bailey, 2022). Varila et al. (2007) found that a time-based accounting system manages costs and efficiency. The accounting information systems have typically utilised the accounting software to manage the orders, stock, return and shipments. Velayutham et al. (2021) argued that managers could use accounting information to cope with the disrupted market logistics and develop robust supply chains. Recently and in a study conducted in Vietnam, Vu et al. (2022) found that accounting systems, particularly strategic management accounting, have a considerable role in the sustainable development of logistics enterprises. However, the accounting information systems for business sustainability that support warehouse operation has not been much discussed in the literature.

This paper aims to investigate the root cause of warehouse underutilisation. The research questions are as follows:

1 What is the root cause of the current warehouse's low productivity?

2 What would be the ideal warehouse space utilisation in the company?

3 What will be the proposed model of a sustainable warehouse?.

The remainder of this paper has been organised as follows. First, the procedural steps of applying the methods are explained after reviewing the literature. Then, the result section will tabulate the findings in the shape of 's for the SVP analysis and equations for the mathematical computation. Following that, the next section discusses the findings, implications and suggestions for the company to choose in accommodating the best scenario for its warehouse. Finally, the last section discusses conclusions whether the research objectives are achieved.

2 Warehouse management

2.1 Warehouse storage

Storage design allocation is the most crucial component that affects the performance of order picking and receiving. There are direct supporting factors that impact the business performance, such as the location of products in the warehouse. The companies need to manage some storage activities to achieve operational excellence, for example, order picking method, size and layout of the storage system, material handling system, product characteristics, demand trends, turnover rates and space requirements. Choosing a good storage assignment policy helps improve the performance of order picking. The storage assignment policies that assign items to storage locations are usually random storage, dedicated storage and class-based storage categories (Fumi et al., 2013). The advantage of this policy is that fast-moving products can be stored near the warehouse, whereas flexibility and high storage space use of random storage is applicable. Frequently, there are two kinds of class-based storage, dedicated purposes and ABC inventory classification (Sooksaksun et al., 2012).

On the other hand, in the picker-to-part method, storage assignment is primarily divided into two categories that are goods and customer orders. For products, Fumi et al. (2013) pointed out that class-based storage, depending on the product characteristics, the picking accuracy can be increased, and order recovery time can be reduced. Furthermore, they emphasised that people should view order recovery time and travel distance as two different performance metrics for order picking. However, their study did not further investigate the relationship between order retrieval time and distance travelled. On the other hand, Cho and Ahn (2021) argued that class-based storage by-product turnover could improve accessibility for pickers of fast-moving items.

2.2 Warehouse performance measurement

A performance measurement system is a set of metrics used to calculate the efficiency and effectiveness of actions (Aminaimu and Fernando, 2021). Even though warehouse performance can be measured into hard metrics (costs, order cycle time, and fill rates) and soft metrics in general, efficiency and effectiveness are the most widely utilised to measure performance (Aminaimu and Fernando, 2021). It has been explored in a lot of ways by scholars. Our works differ from previous studies concerning the objectives' long- or short-term decisions on the warehouse performance. It is argued to plan and design the decarbonisation warehouse activities and measure objectives (variety of performance indicators). The companies need to consider the type of warehouse systems (distribution centre, cross-dock platforms, etc.), the focus area inside the warehouse (storage, picking, etc.) and the tools used for measurement (statistical tools, mathematical programming, etc.) for business efficiency and productivity.

Table 1 Warehouse key performance indicator

	Financial	*Productivity*	*Utilisation*	*Quality*	*Cycle time*
Receiving	Receiving cost per line	Receipts per person-hour	% Dock door utilisation	% Receipts processed accurately	Receipts processing time per receipts
Put away	Put away cost per line	Put away per person-hour	% Utilisation of putting away labour and equipment	% Perfect put away	Put away cycle time (per put away)
Storage	Storage space cost per item	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies	Inventory days on hand
Order picking	Picking cost per order line	Order line picked per person-hour	% Utilisation of picking labour and equipment	% Perfect picking lines	Order picking cycle time (per order)
Shipping	Shipping cost per customer order	Orders prepared for shipment per person-hour	% Utilisation of shipping docks	% Perfect shipments	Warehouse order cycle time

Source: Frazelle (2002)

Warehouse manager needs to choose which type of suitable measurement for their warehouse environment. It is not easy since all the measurements are different (Gu et al., 2010). For example, warehouses could offer various product specifications, customer requirements, and service levels. According to Frazelle (2016), warehouse activities are divided into five movements, i.e., receiving, put away, storage, order picking and shipping. Each activity can be measured using Five key performance indicators (KPI), namely financial, productivity, utility, quality and cycle time. Therefore, there are 25 KPIs for measuring the warehouse, as depicted in Table 1.

2.3 Sustainability

The company has adopted environmental practices to improve performance and attracts stakeholders' attention (Fernando et al., 2022b). According to Foroozesh et al. (2018), some factors are typically used for warehouse management systems:

1 time

2 cost

3 revenue.

Although it is feasible for businesses, not much thought has been given to environmental and social aspects. The conventional indicators focus on economic and efficiency elements, while the social and environmental elements are missing (Fernando et al., 2016). The companies involved in warehousing services must recognise the need for their businesses to consider sustainability issues. Sustainability can help companies preserve their environment and protect human rights and social responsibility (Fernando and Chukai, 2018). Measuring sustainability success will affect decision-making and drive company objectives. Sustainable warehousing is an emerging area, especially conceptualising the sustainable warehouse management system (SWMS). They implemented specific SWMS sustainability metrics considering the three social, economic and environmental dimensions of sustainability. While there are several studies on SWMS performance measurement, the number of studies that fully consider the approach while focusing on all warehouse operations is confined and needs to be enriched. In addition, the comprehensive and precise indicators to assess the sustainability of SWMS have not been developed, and current indicators cannot cover all angles of sustainability.

3 Case study

Four manufacturing companies participated in the study. Most of the companies are located in Selangor, Malaysia, as in multinational group companies majored in hydraulics and factory automation products (FA). Some products include the cranes' gearbox, valve, piston and modular pressure. In addition, there are assembling technology, linear motion technology, and electric drives control.

On average, the manufacturing companies were established in Malaysia between 1980–2001. Besides producing the products, the company operates as a sales and services entity and another branch in Malaysia's central and northern regions. With an average of 71 employees, these four companies have 30 different leading suppliers across the globe. In addition, the companies were deployed 3rd party logistics to support the operations and handle the customer demand. Besides getting raw materials from global suppliers, the companies also received materials from local suppliers. The local suppliers have been deployed to anticipate the uncertainty and support the lead time. On average, the orders shipped to the global market usually take 20 days by sea freight and 7–12 days by air freight. Four manufacturing companies registered logistics couriers, and forwarders are mostly from established global companies. These are the logistics companies responsible for ensuring smooth operations daily.

Even though sales have been increasing for two years, the four manufacturing companies have a common operation problem. The issue of daily operations activities in the warehouse has been lagging and affecting the business performance. It is disputed that the warehouse operations' productivity suffered a drop in the lead time operations. In addition, the workplace environment is not sorted correctly and managed for several reasons. These unfortunate incidents prove to be one of the major problems suffered by this company. Workers are tightening on the lacked space due to flooded inventory of high demand from the customers. They are working hard to pick activities, but the rate seems to fall for unknown reasons. Table 2 the average time taken for warehouse activities.

Table 2 The average time is taken for each process (minutes)/2021

Month	*Receiving*	*Open shipment*	*Pick and pack process*	*Charge out from SAP*	*Prepare outbound shipment*
September	10	15	35	5	10
October	10	15	35	5	10
November	20	30	75	15	15

Table 2. The average time was taken of warehouse activities of a single worker for September, October and November of 2021. Based on Table 2, five major activities affect the productivity of warehouse operations. The first activity is receiving. Receiving is when the company's designated forwarders carry inbound shipments. Later, warehouse personnel must unload the pallet box from the truck and sign the official documents. This process will be lagged on when limited space is available to place the boxes into the warehouse area. Then, open shipment is an activity where store personnel need to unbox the goods and check whether the quantity and type of product are correct according to the purchase order documents provided by the office people.

After all, goods are checked. Accordingly, they will be updated on the systems applications and products (SAP) systems, and the physical stock is then placed on the pallet rack area. This process will require a lot of time if there are no spaces to place the inventory, leading to the worker's initiative to rearrange the stock to make space for the new-coming stock. The third activity is the pick and pack process, where warehouse personnel pick the goods based on the picking slip generated. The physical inventory's not available can cause an interruption in this process, or the items are misplaced at other locations from the SAP systems. Another reason can be the items are placed at the back end or deep down from the pile of pallet racks on the floor. Fourth, the charge out process is when all the required items are available to ship out, and the quantity is deducted in the SAP systems. Finally, the order shipment is the process of loading the goods into the companies lorry and ready to be shipped to the customers. On average, in November 2021, four companies experienced inefficiency in receiving, shipping, picking and processing, handing SAP and outbound shipment Table 2. As stated, the average lead time of each process is increasing every month. This problem decreased the warehouse productivity significantly as the number of lead times decreased, the more the number of completed orders.

4 Methods

4.1 Symptom versus problem (SVP)

SVP defines the root problems identification technique encountered by certain units or organisations. The SVP technique has extended the why-why analysis concept that is divided into several columns called tiers. There is a total of six tiers. Each is related to the other, resulting from asking the question ‘why’ or ‘because of what’. Tier 1 will describe the main issue. For example, the issue proves to be constraint towards achieving the business goals. Then, tier 2 and 3 would be the case issue as it elaborates more on the effects and scenarios that occur due to the main issue in tier 1. Labelled as the case issue, tiers 2 and 3 will be followed by tier 4 to describe the event closer to the main problem. Tier 5 will then describe the main problem to be tackled to achieve the targets. Again, tiers 4 and 5 are labelled as the case analysis as they stated the main problems of this issue. Finally, tier 6 will describe the proposed solution that major businesses need to apply to solve this issue. The strength of SVP lies in a good structure column that enables the company to observe the root cause of the issues structurally. For example, the scenarios can sum up to more than one column for the company to foresee in the case of issue problems. The same function applies to the case analysis in tiers 4 and 5. The wide variability and volumes allow the problems observation process to be crystal clear and, as a result, identifying the problem is much easier. Companies may take this as an opportunity to add more case issues in tier 2 and 3 columns so that all the disastrous problems are identified and need to be tackled in striving the company goals.

4.2 Frazelle model

The Frazelle model is a mathematical approach. This study has classified several major warehouse activities:

1 receiving

2 put away

3 storage

4 order picking

5 shipping.

For the KPI, items are calculated based on the financial, productivity, utilisation, quality and cycle time. For example, if the problem resulting from the first part is from the ‘productivity’ category and about order picking, order lines picked per person-hour mathematical formula is applied. Most performance aspects in the warehouse can apply the Frazelle model. This study showed the steps in finding the storage utilisation rate for the warehouse. The purpose of using this model is not limited to calculating storage utilisation but to increase warehouse capacity in redesigning the layout of the warehouse. This model allows observers to optimise the usage capacity of the warehouse in terms of the space area.

There are three steps to follow when computing:

1 The first step shows the equation of finding the value of usable warehouse space. In this equation, the data required is the full length and width of the warehouse to calculate the area. The area will then subtract the non-storage purpose area, for instance, the workstations, forklift, and stacker parking areas.

2 The usable warehouse space is multiplied by the apparent height of the warehouse space, indicating that the height is crucial in the warehouse storage capacities.

3 The last step shows that the warehouse storage capacities are divided with the total volume of the product multiplied by 100 to produce the utilisation rate.

This method shows the cruciality in collecting the data of pallet box sizes, warehouse space area and the average number of inventories. The data were collected from four companies that interviewed logistics personnel who handle the warehouse and an officer in the purchasing and logistics department. Finally, there are some steps of calculation:

4.2.1 Step 1

$$Uws = S_A - NSP_A$$

$$S_A = \sum S_L \times \sum S_W \qquad NSP_{A=} \sum NSP_L \times \sum NSP_W$$

where

U_{ws} Usable warehouse space

S_A size of the warehouse area

$\sum S_L$ Total length of the warehouse

$\sum S_W$ Total width of the warehouse

NSP_A Non-storage purpose area

$\sum NSP_L$ Total length of non-storage purpose area

$\sum NSP_W$ Total width of non-storage purpose area

4.2.2 Step 2

WSc_3 $U_{ws} \times WSC_H$

where

WSc_3 Warehouse storage capacities

U_{ws} Usable warehouse space

WSC_H warehouse space clear height

4.2.3 Step 3

$$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3} \right] \times 100 \qquad , \sum p^3 = p_l \times p_w \times p_h$$

where

UZ_{ws} Utilisation rate of warehouse storage

WSc_3 Warehouse storage capacities

$\sum p^3$ Total volume of all products

p_l Length of products

p_w Width of products

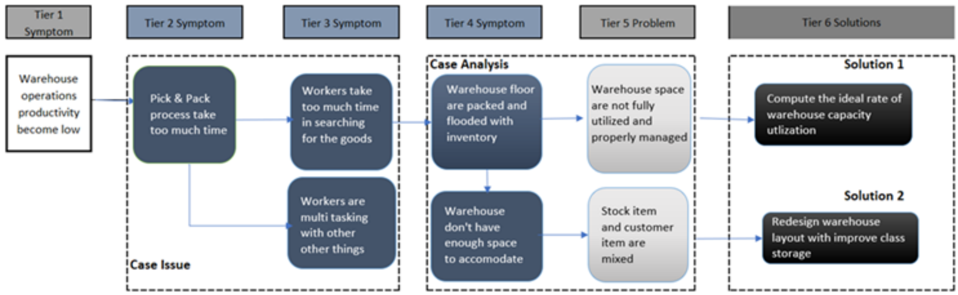
p_h Height of products

4.3 Discrete event simulation (DES)

This study has chosen to perform discrete event simulation on the warehouse operations using Anylogic Simulation software. DES simulates real-world events (Thalamy et al., 2022). In this research, DES can focus on certain activities to provide the necessary detailed information needed by the manager. For example, the total throughput and the lead time taken by the pick and pack process has been formulated. The replication of the process over time has been calculated on the real-life movement of the warehouse activities. It has been observed and visualised without extensive use of the company's financial and staffing resources. Besides, this software calculate the data such as the mean, average and total throughput for the warehouse activity effectiveness based on the item limit and other factors. Based on (Centeno and Carrilo, 2001), there are seven simulation steps. The first step is formulating the issues by reformulating the problem to understand better.

It is due to the unreliable claimed problem with the real problem. Next, collect the required data and information related to the simulation event and construct a conceptual model. The third step is the verification of the conceptual model. Verification is needed to ensure that the process moves in the right direction. Fourth is programming the prototype and running it. Step five is to validate the output of the simulation, whether it is reliable or almost equal to the real-world scenario. Afterwards is experimenting, designing, performing, and evaluating all aspects such as lot sizes, throughput, and the number of products. In this step, several scenarios will be conducted to prove the capabilities of the events under several circumstances and their outcome. Lastly, the simulation is present and run on the computer to view the outcomes and results. The current and the proposed improved layout is shown so that a clear improvement can be observed clearly. Figure 2 shows the former warehouse layout.

Figure 1 The SVP analysis of the warehouse's problems (see online version for colours)



5 Results

The results of this study are discussed in the following sections.

5.1 SVP analysis

Figure 1 demonstrates a structure detail of the SVP analysis where problems, symptoms, and solutions are depicted from tier 1 to 6. It stated that warehouse space utilisation is one of this company's problems. The solution is then proposed as follows. These figures answers and fulfil the first research question and objectives, which are to identify the main problem of this warehouse.

5.2 Mathematical computation of utilisation storage using Frazelle model (Figure 3): Warehouse mathematical computation

5.2.1 Step 1

$$U_{ws} = S_A - NSP_A$$

$$S_A = \sum S_L \times \sum S_W \qquad NSP_{A=} \sum NSP_L \times \sum NSP_W$$

where

U_{ws} Usable warehouse space

S_A size of the warehouse area

NSP_A Non-storage purpose area

$$S_A = 13m \times 25m \quad NSP_{A=} 15m \times 6.25m$$
$$= 325m^2 \qquad\qquad = 93.875m2$$

$= 325 - 93.8725$

U_{ws} 231.1275 $m2$

5.2.2 Step 2

$WSc_3 \quad U_{ws} \times WSC_H$

where

WSc_3 Warehouse storage capacities

U_{ws} Usable warehouse space

WSC_H warehouse space clear height

$231.1275\ m^2 \times 32\ 08\ m^3$

$WSc_3 \quad 7396.08\ m^3$

5.2.3 Step 3

$$UZ_{ws} \left[\frac{\sum p^3}{WSc_3}\right] \times 100 \qquad , \sum p^3 = p_l \times p_w \times p_h$$

where

UZ_{ws} Utilisation rate of warehouse storage

$\sum p^3$ Total volume of all products

One large size wooden box dimension $(s) = (1{,}150mm \times 750mm \times 1{,}150mm)$
$= 0.9918m^3$

One medium size wooden box dimension (s) = $(900\text{mm} \times 650\text{mm} \times 620\text{mm})$
$= 0.3627m^3$

$0.3627m^3 \times 1{,}120$medium boxes = 406.224m^3

One small size wooden box dimension(s) = (750mm n600mm n600mm)
$=0.252m^3$

$0.252m^3 \times 1{,}380$ small box = $347.76m^3$

$\sum p^3$=852.948+406.224+347.73 = $1{,}606.932m^3$

$$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$$

$$\left(\frac{1606.932m^3}{7396.08m^3}\right) \times 100$$

$= 21.73\%$

The maximum storage capacity utilisation is 80%. Therefore, it is proof that the current warehouse is far from achieving the optimum value of storage utilisation. Figure 3 shows the improved warehouse layout.

Figure 2 Former warehouse layout (see online version for colours)

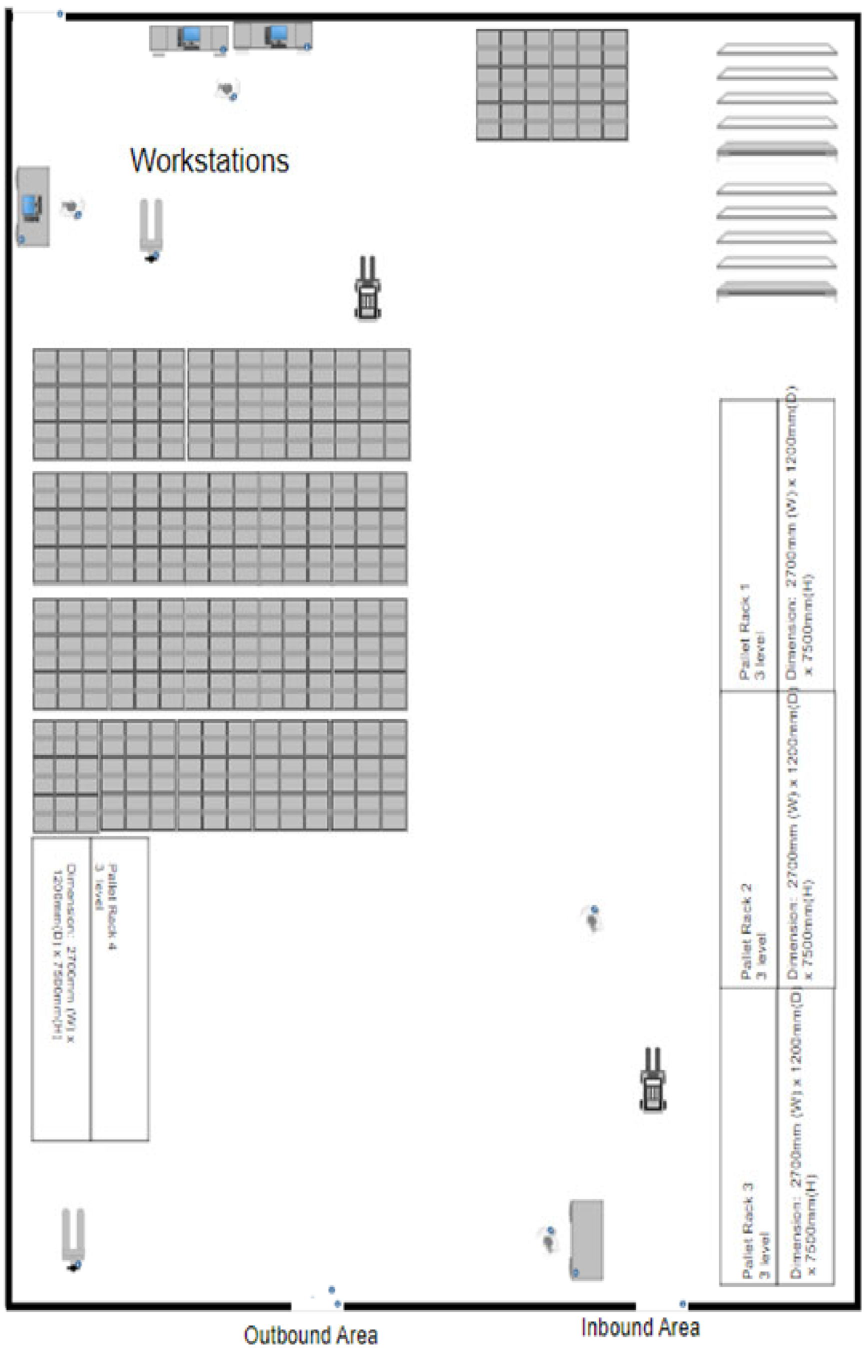
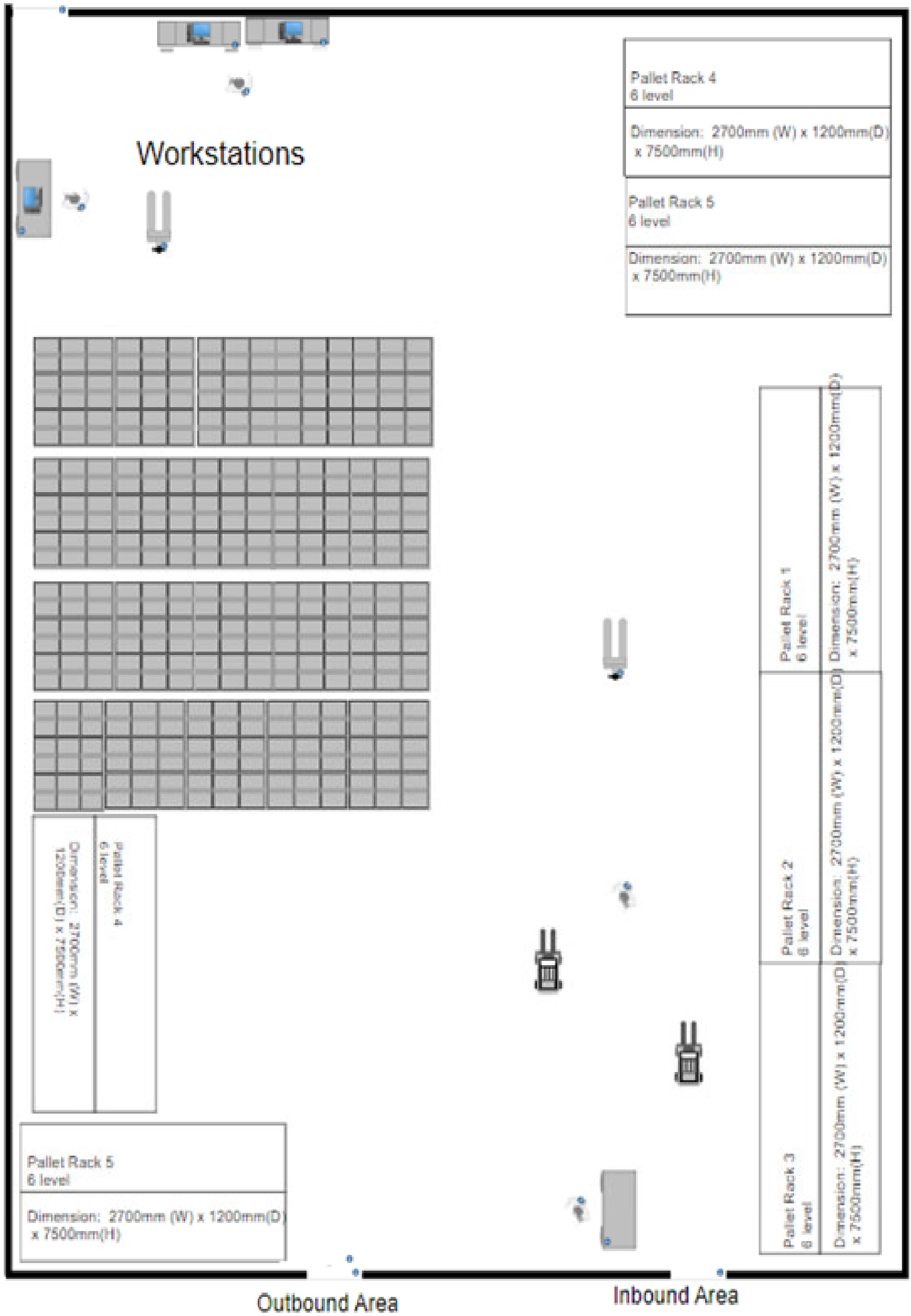


Figure 3 Improved warehouse layout (see online version for colours)



Improved warehouse layout mathematical computation

5.2.4 Step 1

U_{ws} $S_A - NSP_A$

$$S_A = \sum S_L \times \sum S_W \qquad NSP_{A=} \sum NSP_L \times \sum NSP_W$$

where

U_{ws} Usable warehouse space

S_A size of warehouse area

NSP_A Non storage purpose area

$$S_A = 13m \times 25m \quad NSP_{A=} 12m \times 4.25m$$
$$= 325m^2 \qquad = 51m2$$

=325–51

U_{ws} 274 m2

5.2.5 Step 2

WSc_3 $U_{ws} \times WSC_H$

where,

WSc_3 Warehouse storage capacities

U_{ws} Usable warehouse space

WSC_H warehouse space clear height

= 274 m^2 × 32 m^2

WSc_3 8,768 m^3

5.2.6 Step 3

$$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3} \right] \times 100, \qquad p^3 = p_l \times p_w \times p_h$$

where

UZ_{ws} Utilisation rate of warehouse storage

$\sum p^3$ = Total volume of all products in the warehouse

$$\sum p^3 = 852.948 + 406.224 + 347.73 = 1,606.93m^3$$

Plus the total amount of box at external warehouse $= 3,500$

$$\begin{aligned}\text{Box dimension(s)} &= (1{,}200 \text{ mm} \times 800 \text{ mm} \times 1{,}100 \text{ mm})\\ &= 1{,}056\ m3 \times 3{,}500\\ &= 3{,}696\ m3\end{aligned}$$

Plus the total amount of box at Container 1 and Container 3 = 800

$$\begin{aligned}\text{Box dimension}(s) &= (1{,}200\text{mm} \times 800\text{mm n}1100\text{mm})\\ &= 1{,}056m3 \times 800\\ &= 844.8m3\end{aligned}$$

$$\sum p^3 = 1{,}606.93 + 3{,}696 + 844.8 = 6{,}147.73m3$$

$$UZ_{ws} = \left[\frac{\sum p^3}{WSc_3}\right] \times 100$$

$$\left(\frac{6{,}147.73m^3}{8{,}768m^3}\right) \times 100 = 70.11\%$$

based on the improved layout, the storage utilisation rate has reached the optimum value of utilisation rate and still has 10% left to reach the peak value of 80%.

5.3 Anylogic simulation

5.3.1 Current warehouse

Figure 4 showed that the current warehouse floor has a very packed aisle, which caused minimal movement for the warehouse personnel. For example, when the worker is required to look for an item underneath the other boxes, it takes longer to pick that while moving the other pallet boxes using the forklift. Furthermore, the current warehouse only has pallet racks of three-level storage, indicating that the upper space is not being utilised properly.

Figure 5 shows the inbound area of the warehouse where the forwarder came and left the goods to be pickup by the warehouse personnel. Store personnel usually use forklifts to carry the goods as boxes come together with pallet racks. A packed warehouse brings a bad impression towards the company images, which shows that the company has poor management in organising the warehouse inventories.

Figure 4 Shows the current warehouse layout from the inside view (see online version for colours)

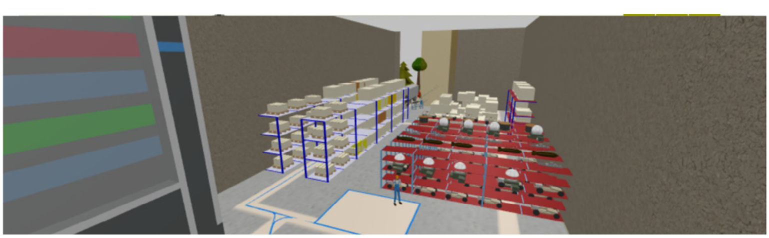


Figure 5 Shows the inbound area of the current warehouse (see online version for colours)

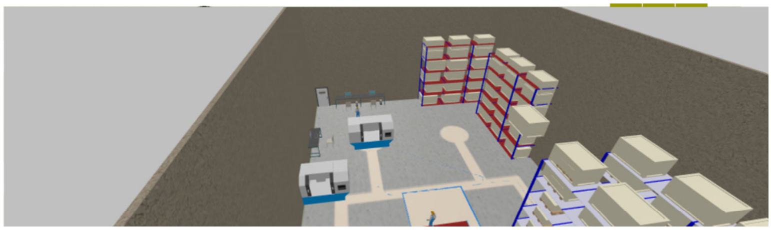


Figure 6 Unused lean lift machines at the corner of the warehouse (see online version for colours)

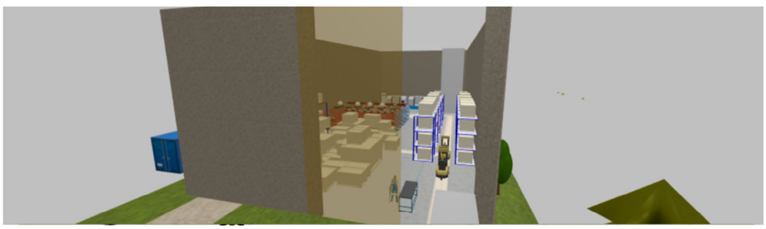


Figure 6 visualised the lean lift machines where some inventory is stored according to the warehouse personnel. Still, due to the physical features of the new products, the lean lift cannot be used any longer.

Figure 7 Overall view of the improved warehouse

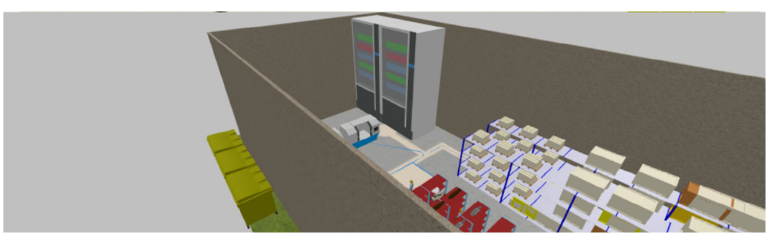


Figure 8 The new install pallet rack near the workstations area

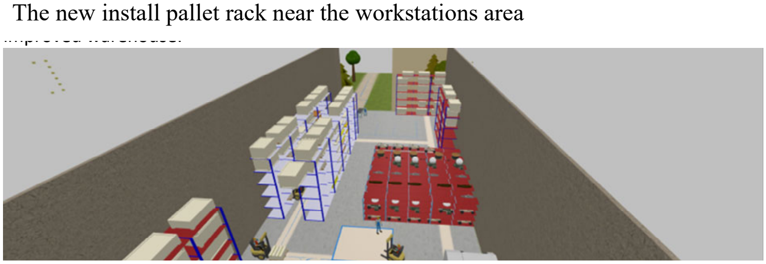


Figure 7 depicts the new, improved warehouse layout with an upgraded level of pallet racks and two additional levels to make it 5. A new pallet rack is also installed at outbound are to maximise the usage of space in the warehouse for the pallet box to store. Whereas in Figure 8, two more pallet racks are installed where before, the lean lift machines are not being used anymore. With all the presence and additional pallet racks consisting of six-level storage, the utilisation rate of warehouse space should increase further.

6 Discussion

6.1 SVP analysis

The result of the SVP analysis has helped this study answer the first research question, which is to identify the reason for the current warehouse's low productivity. Based on the analysis, poor space utilisation may lead to many other problems. As stated in Figure 2, a longer time will be needed when the goods are located far from each other based on the picking slip generated. Due to the nature of product weight and size, we argued that more than 50% of the goods need to be moved by trolley, stacker and forklifts. For example, one picking slip may require 10 – 20 different products to be packed and shipped to a customer per day. The store worker cannot carry all ten products alone without moving back and forth from the workstations to the pallet racks.

So, when the goods are misplaced or put far away from each other due to the lack of space, definitely pick and pack process productivity becomes low. Another symptom highlighted in this study is the stacked floor with pallet boxes on the aisle. For instance, when the store worker requires to pick a product from its bin location, but when checked, it is empty and yet to be restored, whereas, in the SAP systems, it just received a couple of days before. The product is located in one of those pallet boxes on the stacked and flooded aisles. This added the time required to search and move all the pallet boxes and put them back to their old place while picking the needed products based on the packing slip. Subconsciously, this diverts the store worker to multi-task while managing the order picking. It is must organise the open shipment and goods reallocation. These two significant symptoms come from one problem, which is not proper warehouse space utilisation.

6.2 Mathematical computation

6.2.1 Former warehouse utilisation

Mathematical computation based on the Frazelle model allows this study to respond to the second research question to calculate the current rate of warehouse storage utilisation. The current warehouse utilisation rate is 21.73 %, based on the result above. This confirmed that current warehouse management has inadequate storage management. As depicted in the current layout in Figure 5, two lean lift machines prove to consume a lot of space. Based on the formula, height is crucial in determining spaces, as high-level pallet racks usually may utilise that area. The total area consumed by the lean lift is $42m^2$. Every unutilised space is considered a loss. SVP analysis has proved that. In addition, the current pallet rack all has a maximum of 3 level bays, dimensioning of 4,950 mm height of each level. This shows that the pallet rack only consumes 15,000 mm of height, whereas the warehouse clear space height is 32 m. Although there is one factor to consider when bringing a weighty pallet box at a high level, as long as the weight limit of the pallet rack bays and the forklifts is not exceeded, this method may proceed. Crowded floor aisles, as shown in Figure 5 in the inbound and outbound are also played a role in receiving and outgoing shipment activities. These are the few reasons why the current warehouse has a low utilisation value.

6.2.2 Improved warehouse utilisation

In the improved warehouse layout, this study emphasises a few details: to make more space and utilise the area until the maximum clear height. As portrayed above in Figure 7, the lean lift machines have been removed to accommodate two more pallet racks of 5 level bays. This allows the location to store more pallet boxes at the corner of the warehouse, with a height reaching almost 30 m. Furthermore, all the current pallet racks have added two more bays levels to transform them into five levels bays of pallet rack. This action is taken to utilise the empty upper space of the warehouse area.

In addition, another pallet rack is added beside pallet rack four as there are empty spaces were at the current warehouse. Pallet boxes are stacked and placed on the floor. So, a new pallet rack is installed there to prevent untidiness and longer goods searching time, as depicted in Figure 6. As part of the improved layout, we added pallet boxes from the external warehouse and the outside container. Overall, the companies aim to reduce costs and old machinery equipment. Starting from the external warehouse, a substantive amount of RM 10,000 per m^2 is needed to pay for the monthly rental. With a total of 3,500 boxes, at least half a million can be saved on the financial part to invest in another important area. On the other side, storage outside the warehouse building is much safer than inside the container.

Also, the lead time taken in bringing the goods from the container to the warehouse's inside part can be eliminated fully. To sum up, all the goods from the external warehouse and the containers are included in calculating whether the new layout can hold that much inventory. Finally, the calculated value is 70.11 %, where it is an optimum value, considering 80% is the peak value of storage utilisation. If the value is too high, it means the warehouse had a prepare a non-conducive workplace where the movement of the forklift and store worker may be restricted. On the other hand, the too low value of utilisation effects means the warehouse does not use the storage effectively, and the result is presented in the SVP analysis. In short, the improved warehouse layout is proven to have a higher utilisation rate to increase warehouse productivity.

6.3 Warehouse sustainability

This section aims to answer the third research question: What will be the proposed model of a sustainable warehouse. This company does possess ISO 14,000 at bay, but apparently, the warehouse did not practice sustainability that much. Currently, the warehouse uses electric forklifts rather than diesel forklifts. Diesel forklifts require chemical substances to enable the forklift to operate, which leads to water and air pollution. Electric forklifts, however, use electrical power to operate them. The next feature is LED-based lighting. LED-based lighting is considered sustainable as it lasts much longer than normal flour lighting. LED lighting also saves more energy, leading to fewer electric charges and a lower environmental impact. This feature allows the company to save more in cost maintenances and provide less harm to the environment.

Other features that this study proposes to propose a sustainable warehouse model are as follows. The first feature is the proper insulation of the warehouse building. A poorly insulated building makes the cool air escape the structure, resulting in a temperature increase inside the warehouse. A hot working environment is considered poor ergonomic towards the worker, which may lead to exhaustion and the usage of air conditioners that release Chlorofluorocarbon gas and cause the greenhouse effect. Several materials contribute to a sustainable warehouse.

1 Cellulose insulation. 80% of cellulose insulation is made up of recycling material and is environmentally friendly. Very suitable for any commercial warehouse and building.

2 Next is fibreglass insulation, which effectively provides heat insulation. Fibreglass is more suited to install at the roof deck to achieve better insulation. Lastly

3 is the radiant barrier insulation.

The radiant barrier offers great reflection to the radiant coming from the sun. The radiant barrier offers a great reflection of the radiant heat coming from the sun. It helps to keep the warehouse cool as it does not absorb the heat but reflect it to space. Installing on the warehouse roof, radiant barriers are beneficial if you utilise the warehouse for storing things that require low temperature. It consists of reflective material like foil.

In relating to cooling down the temperature naturally, the usage of High-Volume Low Speed (HVLS) fans supports a sustainable aspect as the size of the fans, and their blades make the usage of low speed sufficient to cool the warehouse temperature. The big-blades justify the 'High Volume' aspect in which it can cover a wide array of warehouse areas. Low speed incurred fewer charges on the electricity bills, and low energy release which conserves the environment. the drainage converter system saves the environment by promoting less amount of water consumed every day in the building. As the drain water is collected and transferred to the container that primes towards the non-drinking channel, the amount of water is sanitised more and more daily. Mainly channel towards the toilet and tap water tank, the water consumed daily is only specialised in drinking. Therefore, it will cut the cost of water bills charged to the company.

7 Limitations of the study

This study was conducted during the COVID-19 pandemic and had two months to collect and gather information from the companies and complete this study. Furthermore, we are collecting data from established companies, and it is challenging to make an appointment to meet the warehouse officer. Due to their busy schedule, the author only met 2 to 3 times per month.

8 Conclusions

Managing warehouse productivity while complying with sustainability is a salient topic in today's logistics business. There are a lot of objectives and KPI's to achieve while coping with the ongoing business challenges in nowadays trends. Previous studies have only focused on the general KPI's of warehouse productivity and the fundamentals in terms of warehouse storage. Future studies should focus on the other KPI's such as order picking productivity and cycle time to quantify the performance and aims to achieve the designated target to strive for top performance in warehousing activities. Furthermore, we argued that the warehouse manager needs to consider the operation activities with the cybersecurity governance. Warehouse management systems are vulnerable to cyberattacks (Gani and Fernando, 2021). Despite the ongoing lack of awareness on sustainable warehouses among logistic companies, a previous study did much discussion on the low carbon emission, low energy and other sustainability practices. Still, it did not provide detailed actions that may be taken by other parties to implement it. As the economic and environmental aspect of sustainability has been a highlight in this study, the social aspect of sustainability in warehouse operations should be one of the topics considered for future studies.

The contributions of this study include the improved warehouse layout for the company and the sustainability features using multiple simulation techniques to improve layouts utilisation and sustainability. Furthermore, the capability of the simulation software is demonstrated in producing the discrete event modelling of the warehouse operations. Warehousing is a set of complex activities needed to ensure the logistics part of the business is performing well. Therefore, the effectiveness of each activity is crucial needs to be compatible and performed under any circumstances. In short, all research questions and objectives stated are being answered and fulfilled accordingly. The industry should give more attention to the low carbon warehouse practices. Green practices are part of business success. Fernando et al. (2021) argued that firms need to comply with environmental regulations and remain sustainable over the long term.

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