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Design of Storage Warehouse with Environmentally Friendly Concept: Case Study of ABC Fuel Terminal

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Abstract

This research aims to design a storage warehouse at ABC fuel terminal with an environmentally friendly concept that includes use of renewable energy, building design, ventilation systems, lighting, automation and layout arrangements in storage warehouse. This research uses quantitative research methods to systematically calculate site area based on conditions in field. Total area of this warehouse design is 467.26 m2 with a length of 30.5 m2 and a width of 15.32 m2. In designing an environmentally friendly warehouse, various elements work together to reduce environmental impact. Use of solar panels acts as a renewable energy source that can reduce dependence on conventional electricity. Transparent polycarbonate roof allows natural lighting to enter warehouse, reducing need for electricity for lighting during the day. Rotary ventilation helps to improve air circulation, reduce use of air conditioning, and create a more comfortable working environment. In addition, use of environmentally friendly Material Handling Equipment, such as electric or alternative-fuel forklifts, can reduce exhaust emissions and energy consumption. Finally, application of 3R (Reduce, Reuse, Recycle) principle ensures that waste generated is minimized, resources are used efficiently, and usable materials are not wasted. With this combination of strategies, warehouse can operate sustainably with an environmentally friendly concept. In this warehouse, layout arrangement used is a specialized storage method that dramatically facilitates search, placement, and retrieval of goods.

Keywords: Design, warehouse, environment

1. Introduction

Oil and gas industry is a vital part of a country's economy (Rahayu, 2021). One important product of this industry is fuel oil, which is used in various sectors such as transportation, manufacturing, and power generation (Aprizal et al., 2022). However, amid growing global concerns over climate change and environmental impacts, industry is facing pressure to implement more sustainable practices to reduce carbon emissions and their ecological impacts.

Global need for energy transition and sustainable practices in oil and gas sector is increasingly urgent as countries strive to achieve Net Zero Emission targets and reduce dependence on fossil fuels. Fuel terminals are an important part of fuel supply chain. Fuel terminals are important facilities in receiving, storing, and distributing fuel oil before it is distributed to end consumers. Fuel terminals generally have large stockpile tanks to store various types of fuel (Setiamitra and Subroto, 2023). One of main challenges in fuel terminal operations is loss of products such as Pertalite, Pertamax, Solar, and Biosolar due to evaporation and leakage during distribution and handling process. Following is data on losses at ABC Fuel Terminal. Data regarding fuel losses at ABC Terminal can be seen in Table 1.

Table 1. ABC fuel terminal losses data

Specification	Breathing Loss (Ltr)	Working Loss (Ltr)	Total Losses
2022	492.520	417.165	909.685
2023	486.601	428.180	914.781

As shown in Table 1, total fuel loss increased from 2022 to 2023. It can be seen that in 2022 there were total losses of 909,685 liters. While in 2023 there was an increase in total losses of 914,781 liters. Loss of these products not only impacts economy, but also has a negative impact on environment, as well as potential laws and sanctions that may be faced by

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companies that do not comply with emission regulations (Karmila & Lukman, 2023).

To solve this problem, a workable solution is implementation of a Vapor Recovery Unit (VRU). A Vapour Recovery Unit (VRU) is a system designed to collect and process fuel vapor condensation during fuel delivery process. This VRU system captures vapors produced and returns them to storage tank, thereby reducing product loss and reducing negative impact on environment. This technology not only helps in reduction of carbon emissions but can also provide economic benefits to company through sale of collected gas. In this problem, quantity required for VRU is directly proportional to fuel losses at terminal. Greater losses, more use of VRU to control fuel losses due to losses. However, application of VRUs requires careful economic considerations, including installation and operational costs, as well as environmental impact of applying this technology. On other hand, VRU has been widely used in several countries in oil and gas industry, but its application in fuel terminals in Indonesia is still very limited due to high investment costs required (Rachman and Fathoni, 2017).

Addition of Vapor Recovery Unit (VRU) technology must have spare components intended for replacement or repair in event of damage to machine. These spare components are commonly referred to as spare parts. In this problem, ABC fuel terminal still does not have right warehouse to store operational spare components of this VRU technology. Not only for Vapor Recovery Unit (VRU), ABC Fuel Terminal also requires spare parts for various equipment to ensure operations run smoothly without interruptions that could potentially reduce efficiency. Spare parts are used when a major component is damaged or has decreased performance, while rest are stored in warehouse as strategic stock to ensure operational continuity.

In addition to spare parts, ABC Fuel Terminal also stores chemicals that play an important role in supporting VRU operational performance and Fuel Terminal operations. One of key chemicals is activated carbon which is used in VRU to capture fuel vapors, thereby reducing emissions and increasing reutilization of vaporized fuel. Other chemicals stored in warehouse include lubricants to optimize engine performance as well as fire-fighting foam that serves as a risk mitigation measure. This integration of parts and chemicals availability not only ensures more efficient operations, but also supports ABC Fuel Terminal's commitment to safety and environmental sustainability.

In addition to spare parts, ABC Fuel Terminal also stores chemicals that play an important role in supporting operational performance of VRU and Fuel Terminal operations. One of key chemicals is activated carbon which is used in VRU to capture fuel vapors, thereby reducing emissions and increasing reutilization of vaporized fuel. Other chemicals stored in warehouse include Lubricants play a role in reducing friction and preventing wear between moving surfaces of machines (Sugesti et al., 2024) and optimizing machine performance, and warehouse stores fire-fighting foam that serves as a risk mitigation measure. This integration of parts and chemicals availability not only ensures more efficient operations, but also supports ABC Fuel Terminal's commitment to safety and environmental sustainability.

In an era of ever-evolving industries, it is increasingly important to adopt sustainable concepts. Logistics sector is one area that is receiving special attention, especially through term Green Warehouse (Korra and Sadhana V., 2024). Term green refers to environmentally friendly and resource efficient. This is in line with government's Net Zero Emission movement (Jaradat et al., 2024).

Environmentally friendly aspects of renewable energy and resource efficiency are in accordance with regulations issued by Presidential Regulation of Republic of Indonesia (Perpres RI) Number 112 of 2022 concerning acceleration of renewable energy development for provision of electricity and Regulation of Minister of Public Works and Public Housing (Permen PUPR) Number 02/PRT/M/2015 concerning green building. Thus, concept of a green warehouse can be applied to reduce environmental impact associated with terminal operations. By integrating green technologies such as solar panels, transparent polycarbonate roofs, rotary ventilation, and eco-friendly material handling equipment, fuel terminals can reduce energy consumption and greenhouse gas emissions. In addition, implementation of 3R (Reduce, Reuse, Recycle) activities can reduce amount of waste generated and optimize use of resources. Thus, green warehouse concept can help fuel terminals achieve sustainability goals and reduce environmental impacts.

This research designs a warehouse with a comprehensive approach that considers various aspects ranging from components used, warehouse layout, to storage methods suitable for warehouses at Fuel Terminal ABC. This is what distinguishes previous research conducted by (Syarifudin Arifin and Andesta, 2024) which only focuses on making storage warehouses using dedicated storage method. Whereas this research presents innovation in form of new aspects, namely concept of designing an environmentally friendly storage warehouse. Application of environmentally friendly aspects applied to this warehouse is use of solar panels as renewable energy according to (Sulistiawati and Yuwono, 2019) and use of polycarbonate roofs separately according to (Prianto and Dwiyanto, 2013). Warehousing system used uses references from (Septiani et al., 2020), which states that dedicated storage system is most efficient system in utilizing layout with classification based on frequency of use of goods.

In this research, aspects studied include renewable energy utilization, building design, ventilation systems, lighting systems, automation, and layout arrangements in storage warehouses. These aspects can provide effective solutions in use of renewable energy and resource efficiency (Dianto et al., 2020), as well as being sustainable and having a positive impact on surrounding environment. One of main challenges in fuel storage at Fuel Terminal ABC is problem of evaporation losses, which can be minimized with implementation of a Vapor Recovery Unit (VRU). VRU system plays a role in capturing and reprocessing vaporized fuel vapor, thereby reducing fuel loss while increasing energy efficiency. Therefore, replacement and supporting components of VRU technology in this warehouse design are highly integrated. Environmentally friendly warehouse design is an important aspect to support concept of sustainability, especially in utilization of renewable energy and system automation. In addition, an optimal warehouse layout can also improve operational efficiency by facilitating search, placement, and retrieval of goods, while supporting VRU system in reducing emissions and overall environmental impact.

2. Methodology

2.1. Subject and Object Research

Research subject is source of data covering various variables under investigation, such as individuals (humans or experimental animals), groups, companies, industries, places or geographical areas (Watson, 2015). Subject of this research is ABC Fuel Terminal observed by author. While the object of this research is optimal warehouse layout arrangement so that it can facilitate search for required goods by applying concept of an environmentally friendly warehouse. Goods in question are spare parts and chemicals.

2.2. Type of Research

This research uses quantitative research methods. Based on aspect of calculating location area systematically based on field conditions at Fuel Terminal ABC. Author uses quantitative research because analysis and determination of design carried out is based on area of location where warehouse built and layout of warehouse based on type of goods to store in storage warehouse with an environmentally friendly concept, then a 3D design is made using SketchUp software.

2.3. Data Source

In this study, researchers used secondary data sources, namely all information obtained through indirect research, either through intermediaries or directly from other parties, then recorded. Secondary data is obtained from related companies. Secondary data use in this study are data on area of land build warehouses, Material Handling Equipment used, and goods stored in warehouses at Fuel Terminal ABC.

2.4. Data Collection Technique

Data collection techniques used in this research are literature studies and internal publication data.

2.6. Data Analysis Technique

Analysis technique used in this research is analysis of goods based on function and intensity of use of goods. Items that are often needed are placed near door. Meanwhile, items that are rarely needed are placed far from door. This is applied to facilitate search for goods and access to retrieval of goods.

2.7. Research Flow

In designing an environmentally friendly storage warehouse, a systematic research flow is required. Flowchart of this research is shown in Fig. 1. The research starts from identifying problems that occur at ABC fuel terminals, after knowing problems that occur, next step is to formulate problems and research objectives to help researchers identify core problems to be studied. Such as problem boundaries, literature studies and collection of necessary data.

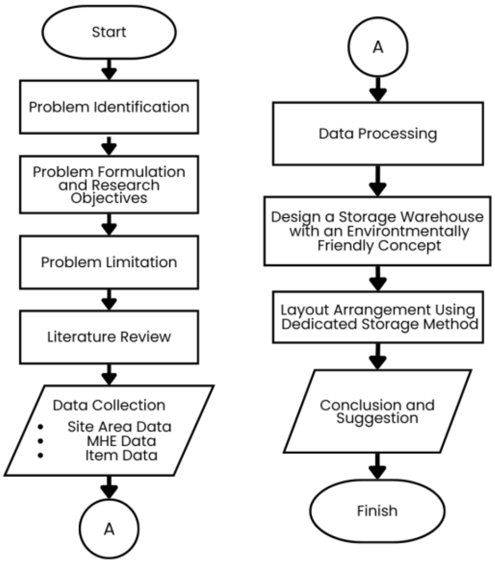

Figure 1. Flowchart research

Data required in this study include location area data, material handling equipment data and goods data at ABC fuel terminal warehouse. After required data is fulfilled, data processing is carried out to obtain more accurate results regarding design of storage warehouses with environmentally friendly concepts. Next step is structuring warehouse layout using Dedicated Storage method. After knowing warehouse layout with an environmentally friendly concept is effective and efficient, next step is drawing conclusions and providing suggestions for future improvements. This research aims to design a storage warehouse with an environmentally friendly concept in minimizing energy use and use of renewable energy in order to reduce carbon emissions and support Net Zero Emission movement in Indonesia.

3. Results and Discussion

3.1. Designing a Storage Warehouse with an Environmentally Friendly Concept

There are several stages in designing a storage warehouse with an environmentally friendly concept.

1) Determination of Building Area

Table 2 is total area of land that has been determined by ABC Fuel Terminal. Area divided into 2 warehouses, namely open warehouses and closed warehouses. Table 3 is area of future open shed used to store used pipes from Fuel Terminal ABC and provide access roads for material handling equipment. Table 4 is area of closed warehouse used to store spare parts and chemicals for Fuel Terminal ABC.

Table 2. Overall building area

Overall		
Specification	Unit	
Area	467,26	m^2
Long	30,5	m
Width	15,32	m

Table 3. Open shed area

Open Shed		
Specification	Unit	
Area	153,2	m^2
Long	10	m
Width	15,32	m

Table 4. Closed Warehouse Area

Closed Warehouse		
Specification	Unit	
Area	314,06	m^2
Long	20,5	m
Width	15,32	m

2) 3-Dimensional Design Creation

After determining building area, next step is to create a two-dimensional and three-dimensional design of storage shed. These designs can be seen in Figs. 2, 3, and 4.

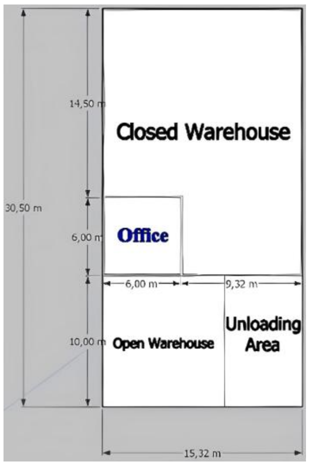

Figure 2. Two-Dimensional warehouse plan

Warehouse layout in Fig. 2 consists of three areas: open warehouse, closed warehouse, and office. Open warehouse stores used pipes, while closed warehouse holds essential goods for ABC Fuel Terminal. Inside, a 6m x 6m office is equipped with computers, printers, and workstations for warehouse management. After designing 2D plan, next step is creating

3D warehouse model.

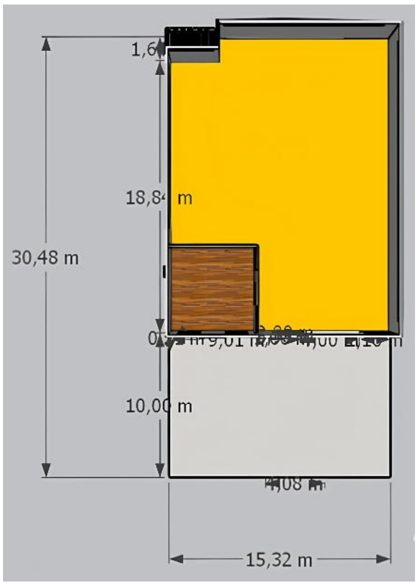

Figure 3. Warehouse visual from inside

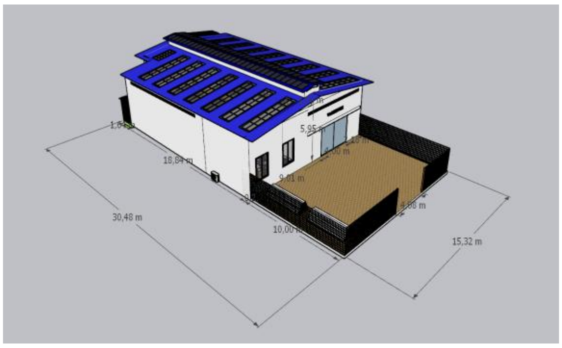

Figure 4. Visual of warehouse from outside

Figure 2 shows warehouse layout in a two-dimensional view, while Fig. 3 and Fig. 4 show inside and outside views of warehouse. Visual model was created using SketchUp application. In design there are additional components such as fences, doors, windows and others. This warehouse has a wall height of 5.95 meters measured from ground. Warehouse is made high in order to provide optimal air circulation.

3) Application of Eco-Friendly Concept in Warehouse

Warehouse adopts various eco-friendly concepts, which are shown in following illustration.

a) Application of solar panels as an alternative power source

First environmentally friendly concept applied is use of solar panels on roof of warehouse so that it can be an alternative power source for warehouse operations. Sunlight captured by solar panels is converted into electricity that use for warehouse operations. Following is an illustration of application of solar panels on warehouse:

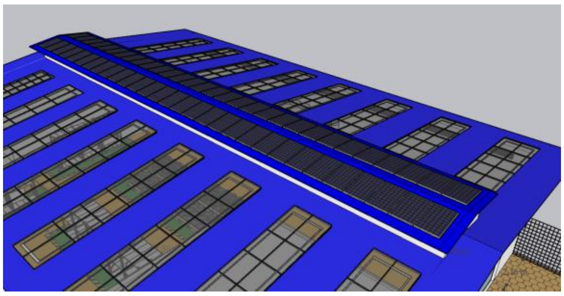

Figure 5. Solar panels on warehouse roofs

In Figure 5 is an illustration of solar panels on warehouse roof. Solar panels has been used by previous research which shows that application of this technology can save energy by 43% and reduce CO_2 emissions by 79.69% (Sulistiawati and Yuwono, 2019).

b) Application of Transparent Roof

Second eco-friendly concept is use of a transparent polycarbonate roof in certain areas. This material, lighter and more durable than glass, allows natural light to enter, reducing electricity use during the day. Polycarbonate roofs has been used by previous studies which show that application of polycarbonate roofs can be installed easily, quickly and for its quality it is strong and durable and can save energy by 9% (Prianto and Dwiyanto, 2013).

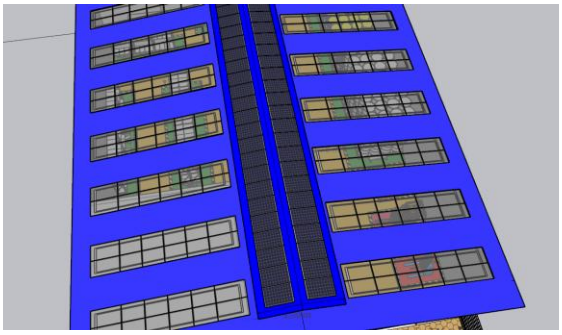

Figure 6. Polycarbonate transparent roof

Figure 6 illustrates use of a transparent polycarbonate roof. Transparent polycarbonate roof is installed on left and right sides of warehouse roof. This innovation can optimize natural lighting in warehouse, thereby reducing dependence on electricity for lighting during the day and significantly improving energy efficiency.

c) Providing ventilation in a circular fashion

Third eco-friendly concept is circular ventilation, installed on warehouse walls and multi-storey roof to optimize air circulation and reduce heat during the day.

Figure 7. Warehouse wall ventilation

Figure 7 shows warehouse wall vents designed around warehouse building to optimize air circulation, reduce heat during the day, and create a more comfortable and energy efficient working environment.

d) Use of environmentally friendly material handling equipment

Fourth eco-friendly concept is using electric forklifts, drum stackers, and handjacks to reduce fossil fuel emissions in warehouse operations. Following is an overview of use of environmentally friendly material handling equipment in warehouse:

Figure 8. Environmentally friendly material handling equipment

Figure 8 shows use of environmentally friendly material handling equipment, such as electric forklifts, drum stakers, and handjacks that can help reduce exhaust emissions in warehouse, and supporting more sustainable operations.

e) Application of automatic light

Fifth environmentally friendly concept is use of automatic lights with sensors that activate only when an officer is present at a rack. This helps locate items easily and reduces electricity consumption by preventing unnecessary lighting.

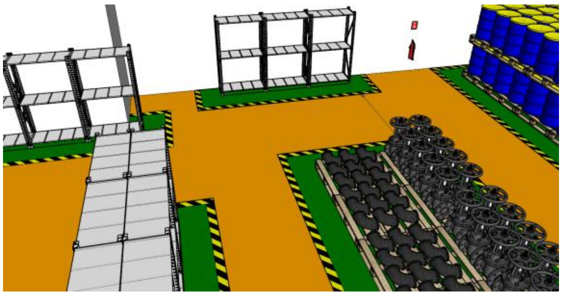

Figure 9. Application of automatic light in warehouse

Figure 9 shows implementation of an automated lighting system in a warehouse enabling energy efficiency with light sensors that turn on only when operators are in certain aisles, thereby reducing electricity consumption and increasing effectiveness of lighting in work area.

f) Use of plastic waste-based paving blocks

Last eco-friendly concept applied is use of plastic waste-based paving blocks for warehouse floor. These paving blocks support 3R (Reduce, Reuse, Recycle) efforts while offering advantages such as strength, lightweight, moss resistance, and better water absorption compared to cement floors.

Figure 10. Paving blocks made from plastic waste

In Fig. 10 is an illustration of paving blocks made from plastic waste, showcasing an innovative approach to sustainable construction materials. From aspects that have been mentioned above, each aspect synergizes and correlates with each other and describes innovations in each picture that are applied in terms of sustainable energy and improving energy efficiency. Each aspect has interrelated challenges. Main challenge of all aspects is high initial development costs and maintenance costs that must be incurred to sustain use of each aspect. In addition to cost issue, another challenge in implementing these aspects is adaptability to keep up with times. Future research can focus on development of automation in environmentally friendly warehouses, exploration of alternative renewable energy sources, and more in-depth analysis of cost efficiency to improve sustainability and operational effectiveness.

3.2. Determination of Warehouse Layout Using Dedicated Storage

Following are stages in structuring storage warehouse layout using dedicated storage method:

A. Item Data Analysis

Following list of items that store in warehouse:

Table 5. Warehouse items data

No	Item	Change of Items (Days)
1	Wearpack	180
2	Safety helmet	180
3	Safety shoes	180
4	Gloves	180
5	Safety Glasses	180
6	Safety Vest	180
7	Cotton Wipe	5
8	Oil Sorbent	5
9	Hose	10
10	Seal	7
11	Oil Paste	7
12	Water Paste	7
13	Flashlight and Battery	20
14	Engine Lubricant (grece/grease)	30
15	Flange	30
16	Lubricant (lithos)	30
17	Gasket	30
18	Filter	30
19	Nut	20
20	Bolts	20
21	Globe Valve	180
22	Gate Valve	180
23	Check Valve	180
24	Reducer	90
25	Flexible Joint	90
26	Elbow	90
27	Foam Drum	180
28	Drum Lubricant	90
29	Activated Carbon	30

Table 5 is a list of items that store in storage warehouse. Furthermore, item data is analyzed based on storage system, storage area, item replacement, and placement of goods in warehouse.

Following is an analysis of item data that author does based on storage system:

Table 6. Rack storage item data

No	Item	Change of Items (Days)	Level Rack
1	Wearpack	180	Level 1
2	Safety helmet	180	Level 1
3	Safety shoes	180	Level 1
4	Gloves	180	Level 2
5	Safety Glasses	180	Level 2
6	Safety Vest	180	Level 2
7	Cotton Wipe	5	Level 1
8	Oil Sorbent	5	Level 1
9	Hose	10	Level 1
10	Seal	7	Level 1
11	Oil Paste	7	Level 1
12	Water Paste	7	Level 1
13	Flashlight and Battery	20	Level 1
14	Engine Lubricant (grece/grease)	30	Level 1
15	Flange	30	Level 1
16	Lubricant (lithos)	30	Level 1
17	Gasket	30	Level 2
18	Filter	30	Level 2
19	Nut	20	Level 2
20	Bolts	20	Level 2

Table 6 shows data of goods stored using racking system. Goods are grouped into three areas based on their function: PPE (1-6), Supplies (7-13), and Spare Parts (14-20). Items with fast turnover (<14 days) are placed on rack closest to door, while items with medium turnover (<90 days) on middle rack, and rarely used items (>90 days) on farthest rack. In addition, heavy items are placed on level 1 rack, while lighter items on level 2 rack.

Table 7. Pallet storage item data

No	Item	Change of Items (Days)
1	Globe Valve	180
2	Gate Valve	180
3	Check Valve	180
4	Reducer	90
5	Flexible Joint	90
6	Elbow	90
7	Drum Foam	180
8	Lubricant Drum	90
9	Activated Carbon	30

Table 7 shows data of goods stored using pallet system, which is divided into two areas: Spare Part (numbers 1-6) and Chemical (numbers 7-9). Goods with a turnover of < 60 days are placed on pallets near door, < 100 days on middle pallet, and > 100 days on farthest pallet.

B. Determination of storage system and material handling equipment

Storage system in this warehouse uses storage racks and pallets. Rack storage can be categorized as small items. Following are specifications of rack used in warehouse:

Table 8. Rack specifications

Specification	Quality
Width	0,5 meter
Long	1,2 meter
Height	2 meter
Level	3

Table 9. Pallet specifications

Specification	Quality
Width	1,2 meter
Long	1,2 meter
Height	0,2 meter

Tables 8 and 9 show specifications of storage racks and pallets determined by Fuel Terminal ABC. Racks are used for lighter items, while pallets store larger spare parts and chemicals. Proper specifications optimize storage space, improve efficiency, and maintain accessibility and safety. Additionally, material handling equipment like electric forklifts, drum stackers, and handjacks enhance productivity by streamlining movement and arrangement of goods.

Table 10. Electric forklift specifications

Specification	Quality
Lifting Power	< 2 ton
Lift Height	< 3 meter
Normal Mast Height	2 meter
Turning Radius	2,2 meter
Total Length	3,6 meter
Total Width	1,1 meter

Table 10 is an overview of specifications of electric forklifts used in warehouse operations.

C. Warehouse Layout Analysis

First step is to calculate space allowance, which is width of warehouse aisle for MHE access. This calculation is based on dimensions of largest MHE, electric forklift. Following is a calculation of space allowance based on dimensions of forklift.

$$Space\ Allowance = \sqrt{Long^2 + Width^2} \quad (1)$$
$$Space\ Allowance = \sqrt{3^2 + 1^2} = 3 \text{ meter}$$

Warehouse aisle width is 3 meters. Racks and pallets are arranged with a 50 cm green picking area, marked with a 15 cm black-yellow line as MHE tolerance limit. A red-marked MHE parking area is placed near door, while floor is colored orange for MHE and staff access. Following is an overview of warehouse layout analysis:

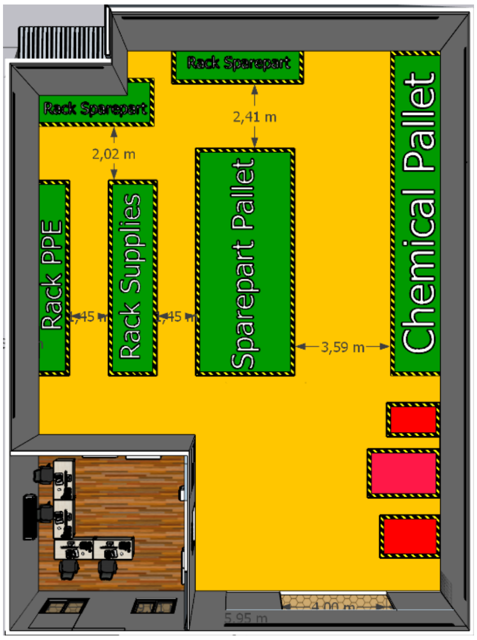

Figure 11. Warehouse storage plan

Figure 11 illustrates warehouse storage plan, depicting detailed layout arrangement designed to optimize space utilization, facilitate efficient material handling, and support an environmentally friendly storage system at ABC Fuel Terminal.

D. Warehouse Layout Arrangement

Warehouse arrangement uses Dedicated Storage method. Dedicated Storage method is applied to make it easier for officers to find items based on frequency of use of goods (Irman et al., 2020). In previous researchers comparing Class Based Storage and Dedicated Storage methods, it was found that Dedicated Storage method is more efficient for MHE's operational performance because based on dedicated storage method, it is grouped only based on frequency of retrieval without seeing if there are similar characteristics of items (Septiani et al., 2020). As a result, storage layout follows a sequence from high to low pickup frequency, optimizing access near entry and exit points. Following is layout arrangement in warehouse :

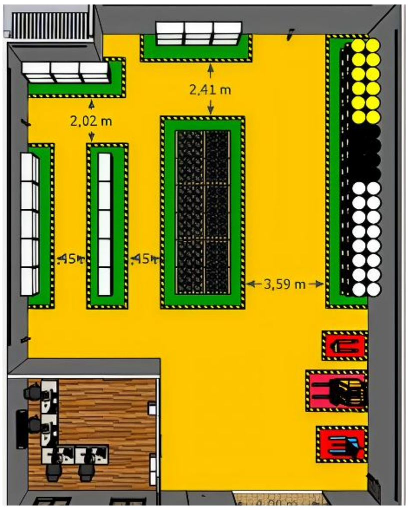

Figure 12. Warehouse layout top view

Following is a more detailed description of layout of each area Fig. 12. shows layout of the warehouse from above, with shelves on the left for small items and pallets on the right for larger items. This layout is supported by 3D components for a more tangible visualization. Here are more details for each area:

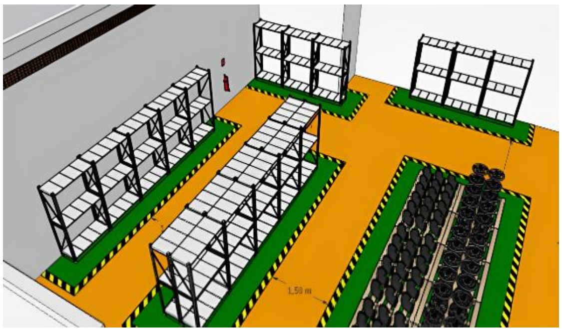

Figure 13. Storage rack area

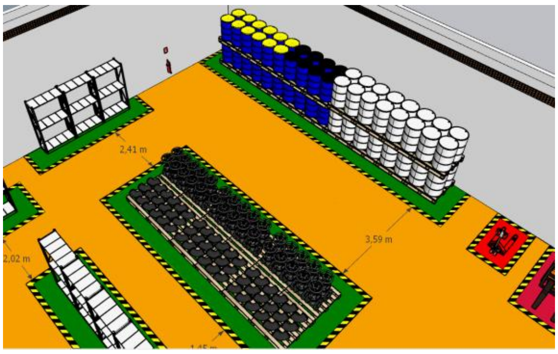

Figure 14. Pallet area

Figure 13 shows arrangement of storage rack in warehouse which has 3 levels on each rack and is also divided into 3 rack areas namely PPE, Supplies, and Spare part areas while Figure 14 shows pallet arrangement in warehouse. Pallet area is divided into 2 different areas, namely spare parts area which functions to store large spare parts and chemicals area to store chemicals in drums.

This research analyzes aspects needed to design an eco-friendly warehouse and its layout. However, data limitations, especially related to construction costs and energy efficiency, make the scope of the study limited and the results do not represent the conditions at large. For future research, it is recommended to expand the scope of data to gain a deeper understanding.

4. Conclusion

Based on research that related to Design of Storage Warehouses with Environmentally Friendly Concepts at Fuel Terminal ABC, it can be concluded that:

1) Designing a warehouse with an eco-friendly concept can create a healthy environment and have a great impact on environment. Examples of implementation include of solar panels, transparent polycarbonate roofs to save energy, optimal ventilation, environmentally friendly material handling equipment, automatic lights, 3R activities (Reduce, Reuse, Recycle) through use of paving blocks from plastic waste. This supports Net Zero Emission movement.
2) Dedicated storage method is suitable for warehouse at Fuel Terminal ABC because it makes it easier to find, place, and retrieve goods. Item analysis is also suitable for this method to store spare parts and chemicals in warehouse.

Author Contribution Statement

I.L.P.: Conceptual framework, literature review, data interpretation. R.B.: Investigation, analysis, writing draft, editing final draft.

Data Availability Statement

The data that support findings of this study are included within article. No additional data were generated or analyzed during current study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence work reported in this paper.

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