

## WAREHOUSE DESIGN AND OPERATION OPTIMIZATION

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### Abstract

Warehouse is one of the critical drives in the supply chain that directly impact the supply chain cost. The efficiency of warehouse operation heavily relies on the effectiveness of warehouse design and layout which is a key decision in the development of the warehouse. The previous research on the warehouse design and layout mainly concentrate to understand the impact of design and layout on the warehouse operation. However, this study has adopted a framework to guide the researcher to quantify the information collected through the interview and secondary data collected from the warehouse performance. This research is exploratory in nature where a case study approach is adopted using a framework to guide the researcher throughout the research process. The finding has provided the researcher with a current state of warehouse performance which was used to develop a new warehouse design and layout to cater to the business growth expectation. This study has provided a different dimension on the measurement of warehouse performance in using a guideline framework which is more reflective as compared to the respondent perception.

**Index Terms**-- Supply Chain Management, Logistic Management, Warehouse Management, Design & Operation optimization.

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### INTRODUCTION

The development of warehouse design is a process to optimize warehouse operations to achieve maximum efficiency in space utilizing, equipment, output, product flow, cost reduction, service to the customers, and provide a better employee working condition (Pokua-duah, 2015). It is perceived that warehouse design is an unpredictable task that generally a result of the various limitation of the warehouse process itself. The complexity is further increased due to numerous activities which aligned with procedures performed inside the warehouse. As a result, numerous perspectives should be viewed and considered during the designing process of a warehouse layout. The warehouse is normally costly to change in regards to facility, equipment, and racks. Hence, it is critical to consider the future interest and adaptability of the changes in future demand during the warehouse layout design process.

Based on this argument, this study attempts to investigate the design optimization of the TECO Electric & Machinery Warehouse operation that facing the unpredictable situation on warehouse utilization due to management decision to change the business strategy by increasing the purchase of material which is currently offered at the lower price by the supplier. This resulted in the overflow of inventory out of the warehouse compartment which exposed the inventory to damage and created disruption in the process flow of goods in the warehouse.

### WAREHOUSE DESIGN AND OPERATION ISSUES

The entire warehouse design problem is bounded to the issue in designing the implement systems, for example, material handling, sorting, storage, and their connection to one another. During the warehouse design process, it always bound to limit the capital and working expenses over a limited period. These make warehouse designs are complicated activities even in cases where proposed design procedures can be utilized. Although various designers illustrate warehouse design issues from various perspectives, there are two main classifications in warehouse planning issues. The primary classification discusses the problem of the general structure and focuses on a top-down approach, repetitive, optimization-based solution formulation. The second classification deals with specific design sub-

problems, such as customer processing or order selection systems (Rouwenhorst et al., 2000).

### WAREHOUSE LAYOUT DESIGN

The layout decision is one of the main facts that determine long-term operational efficiency. The layout has many strategic implications as they set the organization's competitive priorities concerning capacity, process, flexibility, and cost. They are linked to a tactical decision horizon and are dedicated to delivering strategic decisions such as, for example, the location of convenience. The configured production system is input to the operational level, where the goal is to run the system as proficiently a conceivable (Dale, Pilgrim, Dale, & Pilgrim, 2018).

Warehouse design is regularly handled with step by step approaches with interrelated stages and frequent repetitions. The design of the warehouse also addresses the selection equipment and internal arrangement result, which include functional area allocations displaying various designs regarding size, layout, and methods (Bodnar, 2013).

#### A. Warehouse Design Methods

The design process is usually carried out through several successive phases namely concepts, data acquisitions, functional specifications, technical specifications, and equipment selection, layout, and planning and control policy options. Alternatively, these choices might be arranged at a strategic, tactical or operational level. For example, decisions on process flow and automation levels are usually in functional, technical specifications and strategic. Also, the selection of basic storage systems is strategic, while the system dimensions and layout determination are tactical decisions. A detailed control arrangement commonly has a place which is the operational phase.

Starting with limited details, the first rough design is illustrated while at the next stage the design is completed. This is otherwise called as a top-down approach, instead of the bottom-up approach. The perfect plan technique clusters related issues at a similar structure level and determine a solution by optimizing multiple subproblems simultaneously to achieve global optimum.

It is important to identify the relationship between subproblems, to avoid non-optimal solutions.

**B. Warehouse Performance Criteria**

Specific performance criteria are required for the determination of specific warehouse design. In the field of warehousing, it is considered the following criteria: investment and operating costs, quantity and mix of availability, distribution, storage capacity, response time and order performance accuracy. The general significance of specific criteria differs from the type of warehouse. Two types of the warehouse can be recognized which are distribution warehouse and production warehouse.

The distribution warehouse function is to store the product and to satisfy external customer arranges commonly made out of a large number of order lines. The number of various items in a distribution warehouse might be large, while the number per order line might be little, which frequently results in a complex and generally relatively expensive order picking process. Although the purpose of the production warehouse is to store raw materials, work processes and finished products are related to the production and assembly processes, it also could store raw materials and finished products for a long period.

**RESEARCH DESIGN**

A framework developed by Felix Geuken and Louise Jäger( 2015) (see figure 1) was adopted to study the optimization of design and operation at the TECO Electric & Machinery warehouse as shown in Figure 1. This study explores the effectiveness of the warehouse design and its operation as a case study. It is a fact-finding study designed to understand the layout of the warehouse and the storage and distribution of goods and materials at and between the point of origin and destination and

to provide data on the status, condition, and disposal of stored goods for management (Lambert et al, 1998).

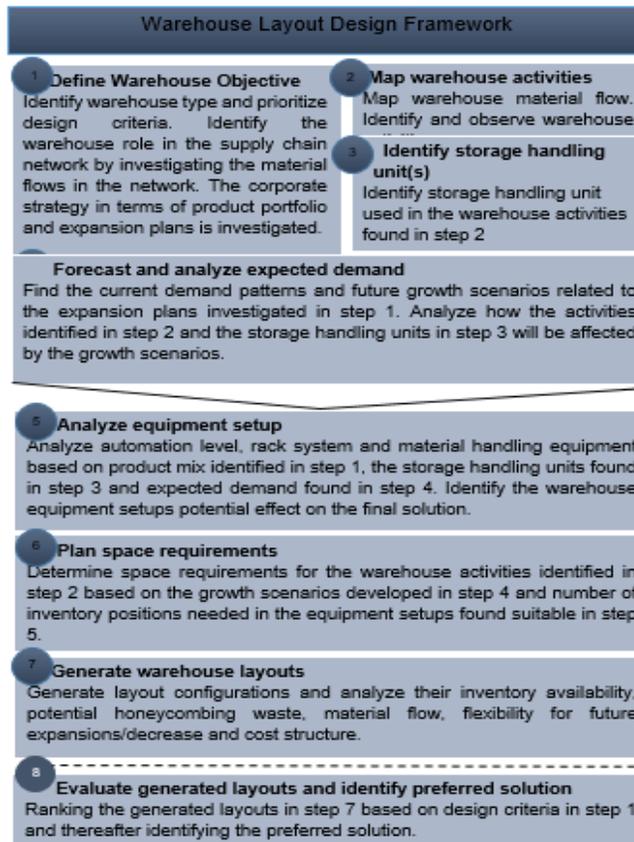
**A. Data Analysis**

Data collection and analysis will simultaneously enable researchers to utilize flexible data collection and facilitate the initial analysis phase (Eisenhardt, 1989). Input data was analyzed per step in the framework to develop the final components of the warehouse design. Frazelle (2002) and Bartholdi and Hackman (2014) describe the analysis profile associated with the activity profile before the warehouse design; customer order profiles, purchase order profile, item activity profile, calendar time profile, activity contact profile, and inventory profile. If the data used in profile activity is an accurate profile, it quickly exposes the problem of design and warehouse design that cannot be seen in the operating warehouse. Therefore, it is important to visualize data to show patterns. (Frazelle, 2002). The profile selected in each framework of the framework developed is described in the following sections.

**B. Warehouse Layout Design Framework**

The improvement of the framework depends on a structure for the literature review. With inspiration from the order of the steps in the arranged design framework, the framework for the layout of the warehouse layout has been developed. It is then filtered through a case study at TECO.

The warehouse layout design framework consists of eight steps that illustrate each of the main steps of the question and output as well as the method of data collection and data analysis proposed to answer them are shown in Figure1.



**Figure 1.** Warehouse Layout Design Framework  
**Source:** Felix Geuken and Louise Jäger (2015)

**RESULTS OR FINDING**

The reporting findings are arranged according to eight (8) steps in the developed framework by Felix Geuken and Louise Jäger (2015).

**Step 1: Define the warehouse objective**

Based on the TECO mission which is committed to providing quality products that fulfill customer, statutory & regulatory requirements”, the warehouse operation is established to execute the company strategies in term of storage activities for production and distribution role to meet the customer requirement.

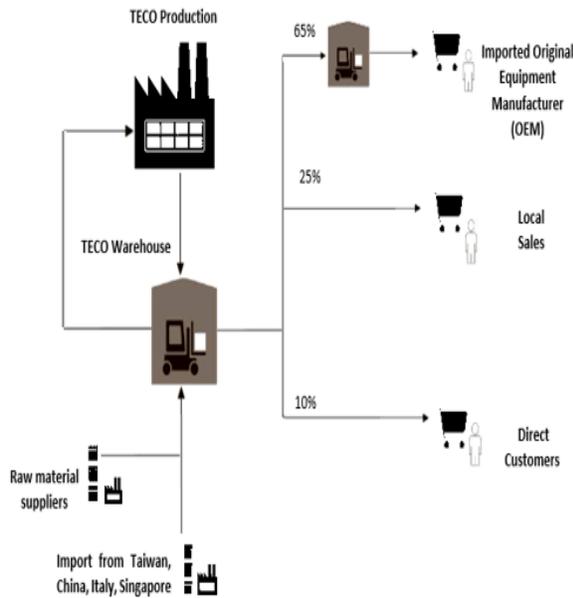
**A. Warehouse types and Design criteria**

TECO has built up a warehouse which is partly to support the production line and also as storage as described in table 1. The design criteria for their warehouse are to minimize the operational cost, to cater to the volume and also occupied the material handling such as pallets.

**Table 1.** Description of warehouse purpose and design criteria

WAREHOUSE TYPE	PURPOSE	DESIGN CRITERIA
Production/Trading	1. Customers demand 2. Store finish products 3. Store raw material	1. Minimize the operational costs 2. Volume and product mix flexibility 3. Warehouse capacity which available pallet positions

Figure 2 shows the TECO supply chain strategy which is typical in a growing phase for large companies. TECO inbound has come from two sources, raw material for the production and OEM products that are mostly imported from Taiwan, China, Italy, and Singapore. This OEM product accounts for 65% of TECO sales, while 25% of other TECO product is for local sales, and the remaining of 10% are to the direct customers.



**Figure 2.**TECO supply chain network

**B. Product Description and Requirements from the Products**

TECO as a leading manufacturer of electrical motor manufacture various types of motors ranging from ¼ HP to 100 HP. Besides standard models, many motors are also made to special

requirements such as different voltages or frequency, insulation class or tailored shafts to suit client specifications. Figure 3 shows several types of products that TECO produced.



**Figure 3.** Part of the TECO product portfolio. From the left the Geared Motors, Brake Motors, Cooling Tower Motors, and Inverter

The primary requirement for the product is cleanliness. TECO very emphasizes the cleanliness because of its products almost 98% is from iron. For this reason, they need to keep their warehouse environment clean, not dusty and not exposed to water to prevent the products from being rust or damaged. Most of the motor produce by TECO are varies according to type and design by the customer according to their requirements.

As such, the TECO inbound purchase is arranged in bulk purchase to avoid any shortage in the production due to supply lead time. For that purpose, the TECO warehouse has implemented a FIFO process which is to prevent any old items stored in their warehouse.

The supply chain approach should be either effective or reactive depending on how demand and supply characteristics are evaluated. Using Lee’s (2002), see figure 4, characteristics for supply and demand uncertainty, TECO’s supply uncertainty is found to be low due to stable production as discussed in table 2.

Two characteristics that deviate from the pattern are that TECO has a limited amount of material supply sources and a possible capacity limitation in output which present in the short term. Meanwhile, the demand uncertainty character is more difficult to determine despite the products have a longer life cycle.

This mainly due to various types of motor that produced for various industries that have created an individual demand uncertainty. In managing this, TECO has added all characteristics in referring to forecasts or demand variations which these uncertainties do not occur weekly, but monthly.

**Table 2.** Supply and Demand characteristics at TECO

Supply Characteristics	Demand Characteristics
Less breakdowns	High demand uncertainties
Stable and higher yields	Long product life
Less quality problems	High inventory cost
Reliable suppliers	High profit margins
Less process changes	High product variety
Potential capacity constraints	
Dependable lead time	

		Demand uncertainty	
		Low (Functional Products)	High (Innovative products)
Supply uncertainty	Low (Stable production)	Efficient supply chain	Responsive supply chains
	High (Evolving production)	Risk-hedging supply chains	Agile supply chains

Figure 4. TECO placement in the supply and demand uncertainty matrix based on Lee (2002)

As can conclude, it is common for machinery industries to have a relatively sure demand that often contributes to the market positioning of the efficient supply chain in the quadrant. For this reason, the findings of TECO products' analysis are confirming that they have an effective supply chain characteristics that influence the warehouse's design criteria to be more oriented on both lowering costs and increasing usage, thus further emphasizing the TECO warehouse's decision criteria.

**Step 2: Map Warehouse Activities**

Figure 4 shows a layout of the TECO warehouse's activities. The mapping has shown that excessive double handling in the warehouse is mainly induced during receiving to minimize honeycombing in processing, shipping, and ancillary activities, in particular the packaging process currently taking place in the warehouse. The packing process is important but non-value adding while the honeycombing reduction movements are a non-value adding movement for the pallet which is why it should be reduced.

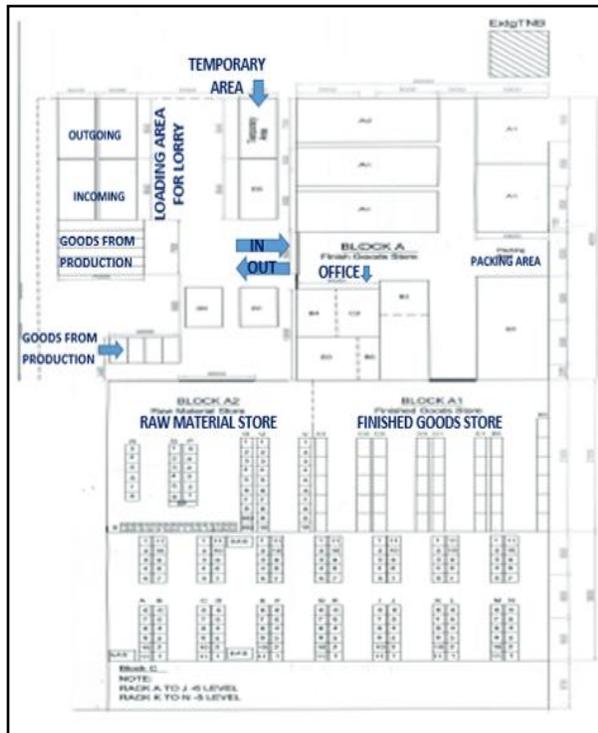


Figure 5. Layout of warehouse TECO

The warehouse is divided into two sections which are for finish goods store and raw material store. Sections of finish goods stores are allocated for products TECO from production and also

from imported. While the section of the raw material store is allocated for the product from supplier to production which is a component of raw material. Other than that, in the area of finish goods stores also have a space for the parking area.

Figure 5 shows a flowchart of the operations carried out at the TECO warehouse. Receiving, put-away, storage, packaging, and shipping are the main activities in the warehouse. Besides these, it also performs the ancillary activities that are the packing process and the office. All their goods are received by the warehouse through the shipping and receiving docks via forklift. The products produced in their warehouse are packaged as ordered by consumers and then put in a lorry or box, which a warehouse worker collects, depending on what form of packaging is applied. For receiving, the flow starts with when the lorry or container arrived (see Figure 6). The staff of the warehouse will check the receiving goods by matching the DO and packing list. If all the documents are matching and verified, the pallets are then moved out of the container with a forklift and placed at the incoming square. Using the lift truck the pallets are then moving into the warehouse and put at the place that has been set.

For shipping, the DO will issue by the sales department to authorize the warehouse staff to move the goods to the packing area using a lift truck. The pallets are then placed on the outside which is the outgoing place. The staff warehouse then loading the pallets into the container using the forklift and products can be shipped.

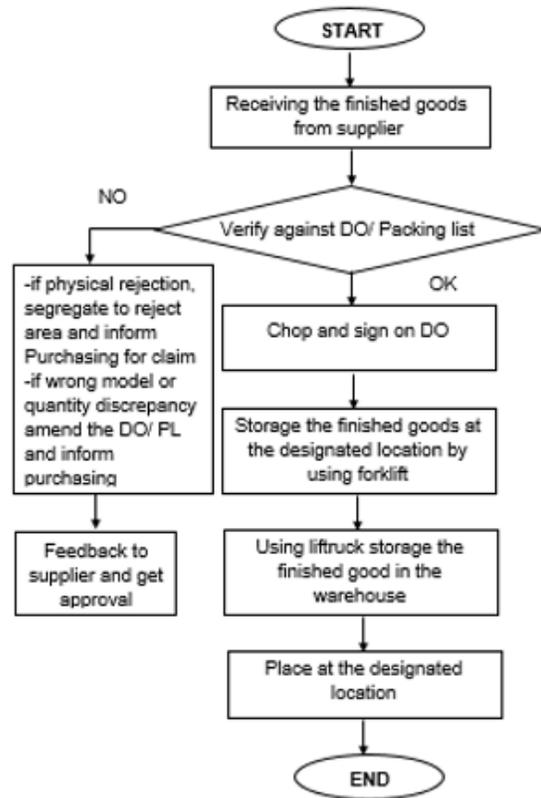


Figure 6. Storing process in TECO warehouse

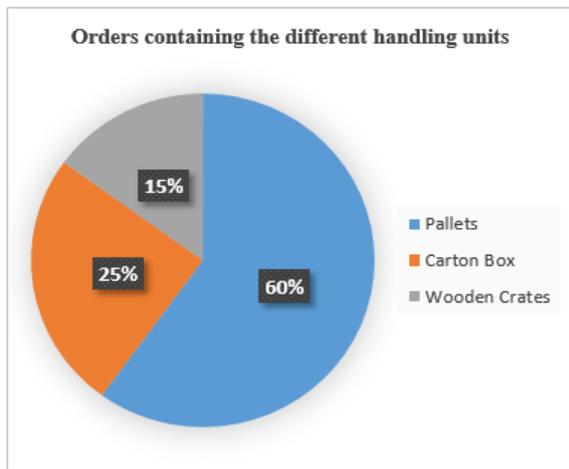
**Step 3: Identify storage handling unit (s)**

The storage handling units used in the warehouse for each activity are mapped and shows in table 3. Pallets, as can be seen, are the main carrier in all operations except for choosing induction engines. Furthermore, for final packaging and storage, the induction motors are immediately put on a pallet.

**Table 3.** Mapping of storage handling unit currently used in the activities within the warehouse process

Storage handling unit	Receiving	Production	Put-away	Storage	Picking	Packing	Shipping
Pallet	X	X	X	X	X	X	X
Wooden crates						X	X
Carton box						X	X
Trolley	X				X		

Pallets are the TECO warehouse's primary load carrier. The induction motors were loaded with not only pallets but also wooden crates and carton containers. However, the proportion of storage handling units used for shipping is based on the estimate from selling orders as shown in Figure 7. Most orders consist only of pallets and sometimes also rely on what customers have ordered, using wooden crates or carton box.



**Figure 7.** Percentage of orders

**Step 4: Forecast and Analyze Expected Demand**

This step will explain regarding current demand profile and also potential future operations. TECO management has set a sales target for the year 2019 at 70 million or an average of 5.8 million monthly. This target is set based on the increasing trend of the global market for induction motors. About 90% of the product stored inside the warehouse will be delivered to the customer upon request, so it is only 10% the finished product will be managed as inventory management. However, the increase towards the global induction motors demand has changes TECO business decision to outsource the production of some of the products to OEM to cater to the increase in demand of the business segment and speed up the supply to the market. This created a new challenge for them in managing the inventory of which more portion of the raw material area has been a surrender to be occupied by the imported finish goods while at the same time maintaining the current production rate. All of these challenges have impacting warehouse planning and operation.

**Step 5: Analyze Warehouse Equipment Setup**

To understand the characteristics and specifications of the goods, it is important to evaluate the warehouse equipment setup as shown in table 4. The setup of equipment should be suitable with the consumer shipping policies which can be aligned with the automation setting. There are different types of equipment setup that are available and being used in the TECO warehouse operation such as a forklift, lift truck, hand jack or also known as

a hand truck, trolley and also crane. For a forklift, it is used for loading and unloading goods from the lorry or container and also being used for a movement or transferring of goods activity within the warehouse area. While a lift truck is used specifically for storing the goods on the rack which is to prevent dust from forklift tires as well as forklift smoke that can affect warehouse cleanliness. For hand jack and trolley, these types of equipment were used to carry goods that less than 20 kilos which are usually using manpower. Lastly, the crane which capable to lift heavy cargo is used in the packaging section to lift or transferring the induction motor for the local or export market.

**Table 4.** Description of equipment

EQUIPMENT	DESCRIPTION
Forklift	<ul style="list-style-type: none"> <li>● Use for loading and unloading from lorry</li> <li>● Use at outside of the warehouse</li> </ul>
Liftruck	<ul style="list-style-type: none"> <li>● Store goods on the rack</li> <li>● Use inside the warehouse</li> </ul>
Hand jack / Hand truck	<ul style="list-style-type: none"> <li>● move the goods on the pallet that placed on the floor</li> <li>● Must less than 20 kg</li> </ul>
Trolley	<ul style="list-style-type: none"> <li>● Carry one or two motors</li> <li>● Less than 20 kg</li> </ul>
Crane	<ul style="list-style-type: none"> <li>● Use for packing</li> </ul>

The benefits from all of the equipment that has been mentioned above are the staff can isolate their daily activities at the warehouse quickly and systematically. While the defect can be caused by damage to one of the equipments which will delay the smooth operation of the day in the warehouse.

Setup of warehouse equipment is the main thing to take care which is the handling of the goods must efficient and the flow in the warehouse must be smooth so that the activity that goes in the warehouse is not interrupted. In the TECO warehouse, the current automation is the use of a lift truck for placing and taking the induction motors from the rack provided in the warehouse. Apart from the lift truck, no automation has been needed for the activities. Due to the weight of TECO manufactured goods, 98 percent of its products are made of iron, so the weight of the induction motor can reach hundreds of kilos per unit.

Therefore, it is not advisable to use an automatic racking system, so the use of a 6-meter lift truck greatly facilitates the day-to-day activities of the TECO.

For warehouse equipment setups it is important to consider the lane depth. In the TECO warehouse, the width of space does not require much space as they use a lift truck. Apart from that, the movement is just 8 feet wide for lift truck movement in each rack lane. For the rack system, TECO is using a manual instead of the system because to finish well that store in the warehouse, the quantity for any space in the rack is very small. This space only can store not more than 4 items, these 4 items regardless of whether the item is large or small, will follow the capabilities of the pallet or the box on which it is placed.

**Step 6: Plan Space Requirements**

The TECO criteria for planning space are based on future demand. This stage the specifications for all activities conducted in the warehouse are prepared to be able to begin the development phase of the warehouse layout when all product

flow is taken back in-house. Apart from put-away, packing and picking, there are more and more operations in the warehouse today. The ancillary activities identified in the TECO warehouse are packaging for local and overseas transshipment as well as for office activities. These activities take up the warehouse space. With improvements made from the pallet to the carton box, the warehouse could reduce the storage space. So, with this conversion, the packing process into the box will take some time but the density problem can be solved in the warehouse. TECO has different types of packaging such as with pallet, wooden crates and also carton box. The use of pallets increases in 2018 but in early October 2019, the use of pallets decreases because the company now more use carton box for shipping as following the customer request. Table 5 showing the use of types of packaging from 2016 until October 2019.

**Table 5.** Types of packaging used

Packaging Years	Pallets	Wooden Crates	Carton Box
2016	3000 pieces	480 pieces	1800 pieces
2017	2850 pieces	520 pieces	1440 pieces
2018	3400 pieces	380 pieces	1650 pieces
Oct 2019	1400 pieces	1800 pieces	2800 pieces

**Step 7: Prepare Possible Warehouse Layouts**

Consideration is given to the design of potential warehouse designs, receiving and shipping docks, the layout of aisles and installation of storage equipment. The main goal of the warehouse layout is to make good use of space and to create the most efficient material handling. Within TECO's latest layout solution, the planned designs all have their starting position. Changes will be made to the format for several reasons. The fast-growing inventory is an important reason for changing the template model. The placement of space in the TECO warehouse for ancillary activities was carried out with their usage frequency and interconnection with other activities. The cost of moving equipment used for various activities was also weighed when considering a move why they are often put in place

The arrangement of the goods in the current warehouse is referred to as the types of the packing that receive from the supplier which is whether a wooden crate, pallet or carton box. The layout for the wooden crate, normally they allocated on the floor by overlapping each other with a height not exceeding 4 meters. Packing on the pallets and carton boxes will be arranged in racks according to their designated locations. If the predefined location is full, the new location will need to be redone and this will take some time and will affect the daily activities.

The storage space for TECO is sufficient but it must be in line with the purchase schedule of the planning stock. Failure to comply with the purchase schedule will not be enough and the area will not be sufficient and they will need to find other ways to place the goods. Apart from that, receiving and outgoing activities should be separate because the goods received and those that are delivered will be mixed, so the separation and delivery can be separated according to several methods which are referred to as time, place and manpower team. For the TECO warehouse, they use the method of time that receiving in the morning and delivery in the evening. Besides, they also use a place isolation method where they will isolate based on the designated areas of the place or square provided.

As the company target each item for each company, if they do not buy the item according to current requirements instead buy in bulk for a high discount and also do not conform to the location

provided there will be warehouse density. When the warehouse is crowded, there will be a lot of busyness and day-to-day activities that are incomplete and inefficient and may result in misplacing of goods or shipping. So, the purchase schedule should be well-defined and there should be good planning for future purchases to avoid any problem as mentioned before happen in the warehouse operations.

**Step 8: Evaluate Generated Layouts and Identify Preferred Solution**

The layout of the warehouse created is evaluated using an evaluated table based on the decision criteria set out in step 1. The analysis table used in this research takes into consideration the versatility of the operating costs, the volume and product mix and the need for storage. The layout suggestion is displayed and evaluated in this step. The suggestion of the layout that is developed and evaluated named layout 1 (see Figure 8). This section is presented with the improvement of the evaluation table, from that point the layout suggestion is evaluated. Layout 1 is evaluated for the current warehouse layout. The preferred solution is then clarified with the possible material flow scenario generated in step 4. From there, the last solution is proposed for the TECO warehouse to rearrange the flow in the warehouse as the most versatile solution.

**A. Evaluation Table for Assessment of Generated Layout**

An evaluation table was developed to evaluate the generated layouts shown in table 6. The design criteria can be found in column one and the basic metric used for the assessment is represented in column two. The development requirements had to do with TECO's warehouse manager. Space requirements, operating costs, product mix, and volume flexibility are the design criteria used. For example, measurements of space requirements in which the absolute numbers are evaluated with the scenario of development created in step 4. The year used for the various tests depends on the solution's future implementation. The measure aims to analyze the direction in which the design capability is and to consider possible layout risks.

It was difficult to predict the future for TECO. The adaptability factor for the rack systems as well as the facility was considered since the existing warehouse was larger planned time. The dimension of adaptability is a qualitative measure intended to characterize the modularity of the design and the warehouse's ability to further increase or decrease the warehouse limit. Investment costs were used as a rough estimate of the cost of building rack costs, and the potential cost of demounting.

**B. Evaluation of the Generated Layouts**

The layout modules generated in step 7 have been combined to layout 1 which is presented and evaluated in this section. In this part, the scores of the layout will be elaborated. The evaluation is conducted between the current layout and layout 1. Layout 1 takes into consideration the redesign of the new building, which is why it aligns with the current layout of the warehouse.

**Table 6.** The scale for the qualitative grading in the evaluation table

Scale	Comment
-	Not good as the current solution
0	Neutral from the current solution
+	Better than current solution
++	Considerably better than current solution

The difference between layout 1 and the current warehouse solution is that the increase of finished goods racks and the decreasing of the raw material rack. This is because the company imported much equipment that is ready from the outside, as the company buys and sells so that the finished goods increase and produce is become decrease. The rack position of the raw material becomes smaller than the finished goods this is because the raw material is coming in the form of separated parts while for the finished goods it comes in the form of the complete setup.

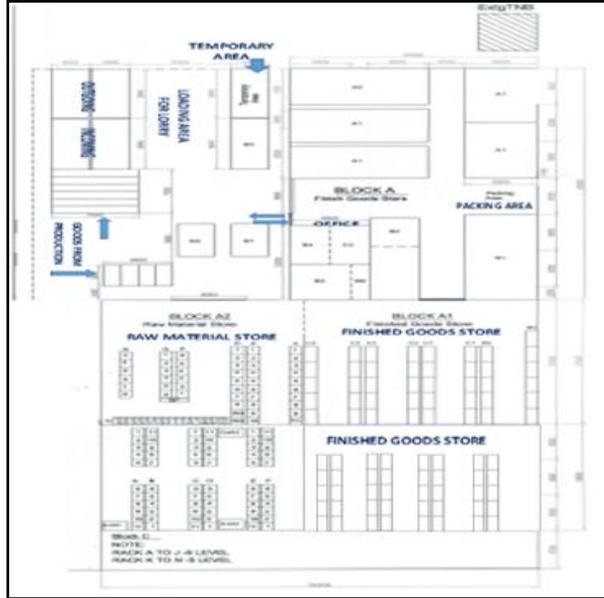


Figure 8. Visualization of Layout 1

The comparison between layout 1 and the current solution is shown in table 7. Disadvantages with the current solutions, other than the lack of provision of square I/O space equipment. As can be seen in table 7, layout 1 reduces rack in place of raw materials. This is a result of better alignment of the rack system to the inflow of both production and operations. After the change, the rack system is better in line with the inflow and outflow which makes storage more efficient and improves pallet position usage. Apart from that, by developing an extension to the facility and purchasing additional rack that would result in the existing pallet position being considered more expensive. The above and below solution capacities are not used in the evaluation between the current layout and layout 1.

Table 7. Evaluation table between the current layout design and layout 1

		Current	Layout 1
Space requirements	Pallet position	930	840
	I/O squares	4	4
Operational cost	Flow efficiency	0	+
Product mix and volume flexibility	Alignment of equipment setup	0	+
	Expansion/decrease flexibility	0	+

**CONCLUSION**

To ensure that every applicable aspect is considered in a legitimate succession when planning a warehouse layout, the framework can be utilized to produce appropriate layout

designs. The warehouse layout design framework created and refined in this research has been created through several steps and carefully selecting frameworks found in the present research on warehouse layout design plan. The last warehouse layout design framework shown in figure 5 which is divided into two sections. The first section is an underlying part intending to characterize the general necessities in the warehouse. For the second section, it is concentrating on the arranging of the facility. By stepwise assurance of the key factors, for example, required pallet positions, goods requirements and goods confinements, the measure of conceivable warehouse arrangements decreases. By delimiting the number of possible solutions for the design early in the advancement procedure more profound investigations can be made on the rest of the choices in this manner bringing about a superior established last arrangement.

Warehouse mapping has the primary purpose of determining the state of the warehouse situation and identify the congestion with the layout. The framework does not include any steps in mapping the storage process to the warehouse. Apart from that, the whole material flow is frequently considered to encourage the layouts and the arrangement of goods. In the case of TECO, the storage process mapping identifies multiple operations due to the packaging process also located within the warehouse.

When taking into consideration of equipment setup, the warehouse layout design framework provides expanded on the adaptability and arrangement with the company. The main goal of this step is the warehouse object, storage handling unit and the predicted demand. The input provides a clear request for the necessary equipment setup. As stated by Bodnar (2013) the warehouse design is regularly handled with step by step approaches with interrelated stages and frequent repetitions. The design of the warehouse design also addresses the selection equipment and internal arrangement result, which include functional area allocations displaying various designs regarding size, layout, and methods. For TECO, the use of pallets is important because most of their products will place on the pallets. Besides, the company needs to use FIFO due to avoid store the goods for a long period.

Based on the framework, the current warehouse arrangement is concerned in all steps of the second part of the framework to guarantee the cost-efficient arrangement. The advantage analysis of potential adaptations of the current framework is analyzed before settling on another layout or equipment setup. The investigation in this case study is where an improvement phase is undertaken to refine the warehouse design framework. The sections of the steps in the process that consider the existing approaches are built by theoretical work rather than updated theory.

The warehouse layout design framework has a clear foundation in the existing literature. Additional focus on forecasting and preparation of current equipment is to offer help to empower the improvement of cost-productive solution development for the time being considered. The warehouse layout design framework is intended to be progressively far-reaching and reasonable for company confronting an uncertain future, for example, emerging companies, in the process of designing and redesigning warehouse operations

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