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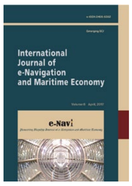

Original article

Selection of The Main Failure Factor Affects the Warehouse Operations Efficiency Using a Fuzzy Analytic Hierarchy Process Technique☆

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Abstract

A warehouse is more than just a place to store goods but also creates a time utility gap between production and consumption that is important in the development of trade and commerce. Malaysia has a high aspiration to be the most popular gateway in Asia. However, Malaysia Productivity Corporation has claimed that particularly in efficiency and productivity aspects, the warehouse industry is less incline to innovate and make improvement to increase. There are ten failure factors that had been identified during literature survey affecting to the warehouse operations efficiency. Therefore, this study intends to analyse and select the main failure factors that mostly affecting the warehouse operations efficiency. A Fuzzy Analytic Hierarchy Process (FAHP) technique has been used in this study to calculate the weight value of each variable through a pair-wise comparison method. The finding highlighted the four main failure factors which are ‘equipment’, ‘environment concern’, ‘special handling consideration’ and ‘human factor’ that influence directly to the warehouse operations efficiency. This paper has contributed to a new knowledge of complex warehouse operation area with recommendations action that shall be taken to manage the possible risk in future, which will also contribute to achieve the government goals.

Keywords: Warehouse Industry, Warehouse Operations Efficiency, Failure Factors, Fuzzy AHP, Multi-Criteria Decision Making Approach

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1. Introduction

Modern logistics system had caused the role of warehouses to become more complicated. It was due to some factors including (1) rapid growth of e-commerce transaction, (2) the necessity for reducing inventory storage, and (3) the demand of faster respond time to the customer or business (Giannikas et al., 2016). Such situation, however, helps to improve product consolidation as well as allows cost reduction through economies of scale (Bartholdi and Hackman, 2008). The management of warehouse is very crucial due to higher level of objective needs to be achieved. For instance, the efficiency of operations, storage capacity and a central location.

Today, the competitiveness among the warehouse business environment becomes crucial in strategizing the global and domestic markets share. This strategy can be done by improving the productivity and efficiency of warehouse sourcing and performance. Sum et al. (2001) claimed that by ensuring the smooth flow of product, information and materials throughout a company's supply chains are the keys to the success by the role of the logistics function (which warehouse is one of the major service providers). However, there have many challenges that influencing warehouse operations which leads to inefficiency productivity, less profit and high operational cost. Thus, this study had recognised several items that influencing the efficiency of the warehouse operation which are 1) stock management, 2) Layout, 3) package design, 4) unitization, 5) communication, 6) basic handling consideration, 7) equipment, 8) human factor, 9) environment concern and 10) special handling consideration.

There are many methods which deals with the decision involving the selection of best alternatives from several criteria or attribute in the literature. Therefore, the most used methods are including fuzzy sets theory, analytic hierarchy process, data envelopment analysis, analytic network process, genetic algorithm, goal programming, simple multi-attribute rating technique, and other methods (Bera et al., 2019; Bera and Jana, 2019). On top of that, this paper denotes an evaluation model that integrates between triangular fuzzy number (TFN) and Analytical Hierarchy Process (AHP) to develop a FAHP method. Also, this paper focuses to analyse and select the main failure factors that mostly affecting the warehouse operations efficiency using FAHP. This paper also provides recommendation for overcoming the challenges that has been analysed for future uses.

2. Literature Review

2.1. Overview of the warehouse

Warehouse is a place for storing goods. According to the Westford School of Management (2016), warehousing is involved in storing the merchandized while involves inbound functions for storing and outbound function of packing and shipping. Warehouse is also determined as the temporary place for storing raw of materials or semi-finished goods before distributing to the wholesaler, retailer, manufacturer, importer, exporter, and others (Kondratjev, 2015). Aminoff et al. (2002) described warehousing as a series or processes or activities undertaken ensuring the flow of material and information. Apart from that, the warehouse also functioned as a place that mixed and altered inventory in order to meet the customer requirement as well as provided storage of goods for economic development (Thomas et al., 1997). During the pre-industrial era, the storage was conducted by individual households which forced the storage facility to function as a self-sufficient economic unit. As transportation capability developed, the product shifted from household to retailers, wholesalers and manufactures. The efficiency of utilization, work method or handling is very important to ensure the warehouses process is enabling to meet the customers' needs. This condition shows that the initial warehouse provides a bridge between production and marketing aspects.

Warehouse operation involves a number of processes which increase the complexity of effective planning which depending on the goods handled by the warehouse and customer requirements are also different (Lam et al., 2015). The main warehouse activities including receiving, transfer and put way, order picking/selection accumulation/sortation, and shipping (De Koster, 2007; Frazelle, 2001; Rouwenhorst et al., 1998). This can be supported by Bowersox et al., (2007) defined warehouse operation divided into three main activities which are (i) receiving – input of cargo, (ii) put-away, storage, order picking and shipping prep – warehouse process, and (iii) shipping – output of cargo from warehouse.

Due to the globalization of logistics and supply chain business activity, the role of warehouse becomes the excellent of distribution hub provided with the real-time information of the activities including receiving, storing and handling of goods (Saifuddin et al., 2013). According to Department of Statistics Malaysia (2016), the current development of warehousing and supporting service activities attributed about RM 29.3 billion (34.1%) in transportation and services gross profit, which was the largest share of output. Also, the second highest workers that engaged in warehousing and support services which was 90,591 employees (31.6%) in year 2014. In addition, the value of gross output generated in transportation and services was recorded increase of about 6.8 per cent per annum with a value of RM43.7 billion in 2015.

The potential growth of the logistics industry as the key to stimulate trade, facilitate businesses and economic growth has received full attention with proper planning by the government of Malaysia through the Eleventh Malaysia Plan (11MP) (MIDA, 2016). Malaysia has set its goal of becoming one of Asia's most popular logistics gates in 2020**.** Therefore, Malaysia government had introduced the strategic framework to resolve bottlenecks in the logistics sector and to develop Malaysia becoming a regional player in the medium term has been well discussed under the Logistics and Trade Facilitation Master Plan (Economic Planning Department, 2015).

As the warehouse activity is important, there is an issue in term of the efficiency of warehouse operations itself. The issue continues to develop with the evolution of the logistics roles (Gundlach et al., 2006). Such situation being a concern in the supply chain system especially in the last two decades, as warehouse was one of the important components in the logistics services (Lambert et al., 1998). Warehouse operation efficiency has become a strategic component that many companies use to improve their position in the market (Tomkins and Smith, 1998). Back to 15 years ago, warehousing industry had been an assisting industry that support other sectors, but now, it has been considered as one of key components in the logistics industry (Gundlach et al., 2006). The changing perspective on the direction of warehouse operations efficiency was due to the competitiveness of global supply chain system and concept that turns the warehouse activities to be more complex (Harmon, 1993). However, due to the numerous challenges being faced in the warehouses operations efficiency, this industry needs more effective and innovative approaches to enhance the warehouse operations (Tomkins and Smith, 1998).

2.2 Factors of Warehousing Efficiency

According to St-Vincent et al., (2005), there were four elements that contribute to the failure factors in warehouse operations which are stock management, layout, equipment and package design. Meanwhile, Fichtinger et al., (2015) found in their research study that stated layout, equipment, environmental concern, basic handling consideration and stock management were categorised as the failure factors that affecting the warehouse operations. This can be supported a research conducted by Anna et al., (2002) mentioned the nine elements contributes to the failure of warehouse operations which were package design, unitization, communication, equipment, basic handling consideration, special handling consideration, layout, environmental concern and human factor. These failure factors are significant and give huge impacts to the efficiency of the warehouse operations. In total, there are of about ten failure factor affects the warehouse operation efficiency has been detected through the literature surveys. Table 1 shows the critical review of these ten criteria with descriptions and some failure cases to be supported.

Therefore, this study intends to find the failure factors of warehouse operations that affect the efficiency of operation it is useful for the decision maker to re-construct the warehouse planning in order to ensure the warehouse operation maintain its efficiency.

Table 1: Critical Review of Warehousing Efficiency and Failure Cases

Criteria	Description	Failure Cases	Citation
Stock Management	The stocker's cognitive activity is to plan the locations for the merchandise in the section	83% of the 90 sequences viewed, the load was either too high or low.	St-Vincent et.al, (2005)
		Mixed up goods caused by no goods arrangement	Paul et al. (2015)
Layout	The characteristics of the displays, space limitations relating to workplace layout and marketing strategy.	Space limitation resulted in access difficulties for stocker in especially frequent width wise (45% of stock pickup and put-down operations); meanwhile, when reaching for the pickup or putdown location directly in front of the stocker (30% accessibility in front of the pickup operations and 39% of the put-down operations).	St-Vincent et al., (2005); Grosse et al., (2017)
Package Design	The standard configuration for product packaging.	The lack of stability of the CU-type packages (29%) than the PU-type packages (71%) constraint to the handling process.	St-Vincent et al., (2005)
		The trend of e-retailing challenges the to the e-fulfillment packaged food warehouse to keep efficiency and maintain the goods state.	Hui et al., (2016)
Unitization	Process of grouping master cartons into one physical unit (containerization)	75% of the company line could not be formed into the clamp able unit load.	Ebeling (1990)
		Order batching problems effecting the delays in order picking activity.	Zare et al., (2018)
Communication	Communication or information transfer in the logistical packaging	The stocker was not having the pallets at the right time	St-Vincent et al., (2005)
		Transmission problems, suppression of information, mistake in what is communicated, type of language used and purposely distortion that leads to employees misinterpret the information give.	Chmielcki (2015)
Basic Handling Consideration	Handling of bulk materials and master cartons are the fundamental difference exists.	An increment in the replenishment rate of new pallets introduced and causing an increase in firm purchase and inventory costs.	Elia and Gnoni (2015)
Equipment	Classified as manual, semi-automated and automated devices	55% of the complaints were technical in nature (requiring problem-solving)	Chakravorty (2009)
		IT supported Human Activity Recognition to replace and reduce the manual order picking.	Reining et al., (2018)
Human Factor	Classified as workgroups, the task of operators to particular workgroups, the role of supervisory personnel, the warehouse leadership and training need for employees.	45% were human factor strife related (requiring conflict in management skills)	Chakravorty (2009); Grosse et al., (2017)
		Miscount, miswritten, and misread during data recording process affecting to stock inaccuracies	Paul, et al., (2015)
Environment Concern	Environment impact of warehouse operations that directly impact from the material handling equipment.	Offshore sourcing increases warehouse emissions by 15% compared to on shoring and 11.3% compared to near shoring.	Fichtinger et al., (2015)
Special Handling Consideration	Identifies and discusses special consideration important to selection and operation of material handling equipment.	Challenges to overhaul the daily operations of inventory level, areas of forklifts and stock keeping unit (SKUs) in real time by using bar-code-based or manual-based warehouse management system.	Faber et al., (2002)
		Challenges to the selection of material handling equipment including physical facility constraints, material characteristics, multiple criteria and uncertainty in the operation and the diversity of material handling equipment.	Eko Saputro, and Daneshvar Rouyendegh, (2016)

3. Methodology

3.1. FAHP Technique

MCDM approach is a set of techniques to structure any problem in a systematically way to assist the decision maker to evaluate the conflict and show a significant part of fairness and accuracy of the conclusion (Bera et al., 2019; Bera and Jana, 2019). This, it helps the decision maker to identify the conflict, comparing and evaluating the alternatives according to the diverse criteria that a way to give the best compromising solution (Zhang, 2010). The significant one that uses MCDM method is AHP. This is because the personal decisions made by the decision maker will impact to other.

AHP is a method that applied in a decision-making situation that brings to the multiple or conflicting criteria. This method was developed by Saaty (1980), and it is an effective technique to deal with a complex decision-making situation. This method basically used pairwise comparison matrix as a measurement ration scale that being determined based on the expert's judgment in evaluation process (Zhang, 2010; Abdul Rahman and Ahmad Najib, 2017). The comparison between criteria is conducted using a pair-wise comparison model that incorporated with a fundamental scale of absolute numbers (Abdul Rahman, 2012). In the AHP process, a hierarchy structure is formed to analyse the problem. It can consist of several levels, including goal (at the top level), criteria, sub-criteria or alternatives (at the successive or lower levels) (Rahmatdin et.al., 2018). The priorities (weight) of each criterion in the hierarchy will found where each criterion will be compared with the parent criteria (Russo and Camanho, 2015; Rahmatdin et al., 2018). This method can help decision maker to analyse their choices in order to make the best decision.

The FAHP technique can be viewed as an advanced analytical method developed from the traditional AHP. According to Deng (1999), AHP method is often criticized due to its use of unbalanced scale of judgements and its inability to adequately handle the inherent uncertainty and imprecision in the pairwise comparison procedure. Since the traditional AHP method seems to be problematic in the uses an exact value to express the decision makers opinion in a comparison alternative (Wang and Chen, 2007), to overcome all the lacking, the FAHP was developed to solve the hierarchical problem (Ayag and Ozdemir, 2006). Ozdagoglu and Ozdagoglu (2007) claimed that classical and fuzzy methods are not a competitor with each other at same conditions. However, if the information/ evaluations are certain, classical method should be preferred and if the information/ evaluation are not certain, FAHP method should be preferred. Thus, FAHP method improves accuracy compared to classical AHP method.

The AHP method tends to be less effective when dealing with uncertainty or vagueness characteristic (Zaied et al., 2018) and thus, led to the association with the Fuzzy Set Theory (FST) by Zaedah (1965). Javanbarg et al. (2012) described the linguistic terms are the value in the real unit interval which translate the vagueness and imprecision of human thought, while triangular and trapezoidal fuzzy numbers addressed to capture the vagueness of the parameters. In addition, the fuzzified Saaty's 1-9 scales is used to represent the numerical values and linguistic variables in triangular fuzzy numbers and trapezoidal fuzzy numbers (Kabir and Hasin, 2011; Rodcha et al., 2019). TFN is a special case of a trapezoidal fuzzy number when the two most promising values of a trapezoidal fuzzy number are the same number (Chen et al., 2015). TFN are often used in the application of FST due to its computational simplicity and efficiency in representing and processing information (Ertugral and Karakasoglu, 2009; Chen et al., 2015). Therefore, relevant linguistic variables have been used in the pair-wise comparison in which can be represented in the form of the TFN when denoting the FAHP method (Srichetta and Thurachon, 2012). Hence, in this study the TFN in FAHP is adopted.

A set of TFN is simply denotes as (a, b, c) to illustrate the lower possible value, the promising value and the largest value respectively. A TFN can be described as in Eq. 3.1, while the reciprocal of the triangular fuzzy numbers can be expressed as (1/a, 1/b, 1/c).

$$\mu(x) = \begin{cases} 0 & x < a \\ (x-a)/(b-a) & a \le x \le b \\ (c-x)/(c-b) & b \le x \le c \\ 0 & c \le x \end{cases}$$

Then, the aggregation of the pair-wise comparison and calculation of weight vectors are performed to choose the main attribute from the overall priorities of the decision criteria or alternatives. AHP has been chosen in this study because it is enabling to identify and rank the important criteria based on their priority in the hierarchy process. This process enables to assist decision makers in the warehouse operations to deal with the dynamic of daily business activity.

3.2 Data Collection Process

There are eight experts (Table 2) from different warehousing companies have been selected to contribute their ideas, opinion and decision in answering a set of questionnaires concerning the failure factors affect the warehouse operations efficiency. The criteria of selecting the experts are as follows: 1) the expert should at least directly have involved in the warehouse operations for a minimum of 5 years' experience; 2) the experts must be categorized as a decision maker in the company; and 3) holding a position at least Executive level and above. In this step, the experts also give the opinion and the judgment to the issue.

Table 2: Experts' Descriptions

Company	Experience (year)	Position
Petikemas	10	Manager
Mitsui-Soko (M) Sdn Bhd	22	Manager
Century Logistics Holding Berhad	26	Senior Manager
Scaffolding	5	Technical Executive Operation
Pacific Logistic Corporation	5	Business Development Manager
Tamadam Bonded Warehouse	30	Manager
Mine Warehouse	5	Manager
LSM logistics & Warehouse Sdn Bhd	20	Executive

The fuzzy triangular scale and pair-wise comparison techniques are used in this study to determine the relative weight value of each criterion. Then, the pair-wise comparison is performed to all the criteria by applying a ratio scale assessment. The assessment scale is shown in Table 3.

Step 1: Decision Maker compares the criteria or alternatives via linguistic terms shown in Table 4.

Table 3: Linguistic Terms and the Corresponding Triangular Fuzzy Number

Saaty scale	Definition	Fuzzy Triangular Scale
1	Equally important (E. Imp)	(1,1,1)
3	Weakly important (W. Imp)	(2,3,4)
5	Fairly important (F. Imp)	(4,5,6)
7	Strongly important (S. Imp)	(6,7,8)
9	Absolutely important (A. Imp)	(9,9,9)
2	The intermittent values between two adjacent scales	(1,2,3)
4		(3,4,5)
6		(5,6,7)
8		(7,8,9)

Source: Ayhan, 2013; Moslem et al., 2019

For example, if the criteria 1 (C1) is fairly important then criteria 2 (C2), the fuzzy triangular scale will be as 4, 5, 6. The meaning of values 4, 5, 6 in this case is (4 = low boundary, 5 = median and 6 = upper boundary). In contrast, the pair-wise comparison of C2 to C1, the answer of fuzzy triangular scale will be 1/6 (lower boundary), 1/5 (median), 1/4 (upper boundary). The experts will compare the criteria by using the linguistic terms as described in Table 3. The steps of this particular calculation procedure are shown as follows:

Step 1: The pair-wise comparison matrix is shown in Equation 1, where $\widetilde{d_{ij}^k}$ indicate the k^{th} decision maker's preference i^{th} criterion over j^{th}, via fuzzy triangular number. Here, "tilde" represents the triangular number demonstration.

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{d_{11}^k} & \dots & \widetilde{d_{1n}^k} \\ \dots & \dots & \dots \\ \widetilde{d_{n1}^k} & \dots & \widetilde{d_{nn}^k} \end{bmatrix} \quad (1)$$

Step 2: If there is more than one of decision maker, then preferences of each decision maker ($\widetilde{d_{ij}^k}$) averaged and ($\widetilde{d_{ij}}$) is calculated as shown in Equation 2.

$$\widetilde{d_{ij}} = \frac{\sum_{k=1}^{k} \widetilde{d_{ij}^k}}{K} \quad (2)$$

Step 3: According to averaged preferences, pair-wise contribution matrices is updated as shown in Equation 3.

$$\tilde{A} = \begin{bmatrix} \tilde{d_{11}} & \cdots & \tilde{d_{1n}} \\ \vdots & \ddots & \vdots \\ \tilde{d_{n1}} & \cdots & \tilde{d_{nn}} \end{bmatrix} \quad (3)$$

Step 4: A fuzzy comparison values of each criterion is calculated as shown in Equation 4. Here $\tilde{r_i}$ still represents triangular values.

$$\tilde{r_i} = \left(\prod_{j=1}^{n} \tilde{d_{ij}}\right)^{1/n} \text{, i= 1, 2, … ,n} \quad (4)$$

Step 5: The fuzzy weights of each criterion can be found with Eq. 5, by incorporating the next three sub steps.

Step 5a: Find the vector summation of each $\tilde{r_i}$ **Step 5b**: Find the (-1) power of summation vector. Then, replace the fuzzy triangular number, to make it in an increasing order.

Step 5c: To find the fuzzy weight of criterion i ($\tilde{w_i}$). Next, multiply each $\tilde{r_i}$ with this reverse vector.

$$\tilde{w_i} = \tilde{r_i} \times (\tilde{r_1} + \tilde{r_2} + \cdots + \tilde{r_n})^{-1}$$
$$= (l\tilde{w_i}, \chi\tilde{w_i}, u\tilde{w_i}) \quad (5)$$

Step 6: Since $\tilde{w_i}$ are still in fuzzy triangular numbers, it needs to be de-fuzzified using Centre of area method proposed by Chou and Chang (2008), by applying Eq. 6.

$$M_i = \frac{lw_i + \chi w_i + uw_i}{3} \quad (6)$$

Step 7: M_i is a non-fuzzy. However, it needs to be normalized by following Eq. 7.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (7)$$

There are the seven steps used in finding the normalized weight value of each criterion. By using Fuzzy AHP method, the main failure factors affect the warehouse operations efficiency can be determined and rank based on the priority.

4. Findings

4.1. Model Development

The development of model was constructed by using the literature survey as summarized in Table 1 and has been verified by the selected industrial experts as per described in Table 2. In total, there are ten criteria which have been identified as failure factors in affecting the warehouse operations efficiency in Malaysia. The model of this study has been constructed as shown in Figure 1 which consisting of two components, 1) goal and 2) ten failure factors.

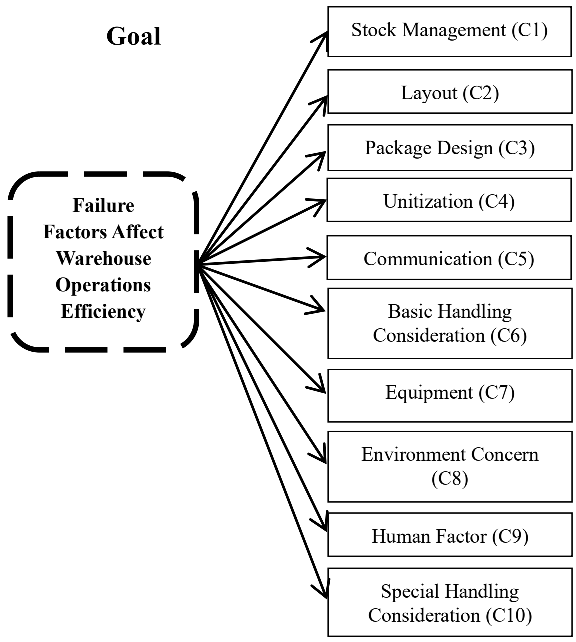

Figure 1: Model Development of Failure Factors affects the Warehouse Operations Efficiency

4.1.2. Data Analysis

Steps 1, 2 and 3: Construct a pair-wise comparison matrix and perform judgment of pair-wise comparison. The pair-wise comparison matrix size 10x10 is created. In this step, the scale values of all pair-wise comparison have recorded. Next, the experts will give scale value to the each of criteria and it is computed and divided by the total number of the eight experts according to Equations 1, 2 and 3. Then, such an algorithm was conducted for each criterion in pair-wise comparison in order to determine the weight value of each criterion.

Therefore, the demonstration calculation of the pair-wise comparison for the matrix C1 versus C2 is shown as follows:

E1: (9,9,9), E2:(1/9,1/9,1/9), E3:(9,9,9), E4:(1,1,1), E5:(1,1,1) E6: (1/9,1/8,1/7), E7: (7,8,9) E8: (1,1,1)

where, E1 stands for Expert 1, E2 = Expert 2, E3 = Expert 3 until E8 = Expert 8.

Lower boundary $:\frac{(9+\frac{1}{9}+9+1+1+\frac{1}{9}+7+4)}{8} = 3.528;$

Median $:\frac{(9+\frac{1}{9}+9+1+1+\frac{1}{8}+8+1)}{8} = 3.655;$

Upper boundary $:\frac{(9+\frac{1}{9}+9+1+1+\frac{1}{7}+9+1)}{8} = 3.782$

According to the fuzzy AHP, in contrast to the pair-wise comparison for the matrix C2 versus C1 is known to be as follows:

Lower boundary $:\frac{(\frac{1}{9}+9+\frac{1}{9}+1+1+7+\frac{1}{9}+1)}{8} = 2.417;$

Median $:\frac{(\frac{1}{9}+9+\frac{1}{9}+1+1+8+\frac{1}{8}+1)}{8} = 2.543;$

Upper boundary $:\frac{(\frac{1}{9}+9+\frac{1}{9}+1+1+9+\frac{1}{7}+1)}{8} = 2.667$

Further detailed information of the pair-wise comparison data set for the ten criteria is summarized in Table 4.

Table 4: Averaged Pair-wise Comparison Matrix for Ten Criteria

CRITERIA	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	(1,1,1)	(3.528, 3.655, 3.782)	(2.087, 2.363, 2.682)	(2.795, 3.301, 3.810)	(1.424, 1.555, 1.688)	(2.778, 3.281, 3.788)	(1.313, 1.443, 1.577)	(0.451, 0.456, 0.462)	(3.034, 3.541, 4.049)	(2.046, 2.3, 2.557)
C2	(2.417, 2.543, 2.667)	(1, 1, 1)	(2.643, 3.146, 3.650)	(1.679, 1.939, 2.202)	(0.563, 0.572, 0.585)	(1.905, 2.158, 2.289)	(0.563, 0.568, 0.577)	(0.921, 1.050, 1.182)	(0.376, 0.411, 0.495)	(1.321, 1.458, 1.602)
C3	(3.028, 3.406, 3.786)	(1.092, 1.246, 1.445)	(1, 1, 1)	(0.457, 0.468, 0.484)	(1.903, 2.156, 2.411)	(1.063, 1.197, 1.335)	(0.567, 0.576, 0.591)	(0.573, 0.589, 0.616)	(1.803, 2.186, 2.199)	(1.674, 1.928, 2.184)
C4	(2.574, 2.963, 3.359)	(3.625, 4.125, 4.625)	(4.250, 4.75, 5.250)	(1, 1, 1)	(0.567, 0.578, 0.595)	(0.963, 1.109, 1.272)	(0.684, 0.698, 0.723)	(0.918, 1.049, 1.182)	(0.818, 0.954, 0.970)	(1.172, 1.310, 1.458)
C5	(3.014, 3.266, 3.518)	(2.160, 2.416, 2.674)	(2.285, 2.541, 2.799)	(3.5, 4, 4.5)	(1, 1, 1)	(0.573, 0.589, 0.612)	(0.686, 0.700, 0.726)	(1.032, 1.161, 1.293)	(0.943, 1.073, 1.210)	(0.689, 0.692, 0.699)
C6	(2.075, 2.340, 2.612)	(4.125, 4.375, 4.625)	(2.661, 3.036, 3.414)	(2.521, 3.025, 3.531)	(3.375, 3.875, 4.375)	(1, 1, 1)	(0.678, 0.686, 0.699)	(1.424, 1.556, 1.692)	(1.553, 1.813, 2.077)	(1.033, 1.161, 1.286)
C7	(4.013, 4.266, 4.518)	(4.125, 4.375, 4.625)	(3.750, 4.120, 4.500)	(2.6250, 3, 3.375)	(2.500, 2.875, 3.375)	(2.625, 3, 3.375)	(1, 1, 1)	(2.014, 2.264, 2.514)	(2.639, 3.016, 3.393)	(2.286, 2.543, 2.803)
C8	(4.375, 4.500, 4.625)	(3.150, 3.406, 3.662)	(3.100, 3.350, 3.600)	(3.025, 3.406, 3.787)	(2.150, 2.406, 2.662)	(2.764, 3.141, 3.518)	(1.785, 1.791, 1.799)	(1, 1, 1)	(2.141, 2.518, 2.895)	(2.291, 2.549, 2.807)
C9	(1.693, 1.954, 3.220)	(4, 4.750, 5.500)	(2.410, 2.711, 3.174)	(3.150, 3.656, 4.167)	(2.400, 2.531, 2.667)	(2.545, 2.932, 3.330)	(1.425, 1.558, 1.694)	(1.314, 1.453, 1.601)	(1, 1, 1)	(1.668, 1.927, 2.182)
C10	(3.030, 3.283, 3.414)	(3.139, 3.641, 4.1413)	(3.161, 3.292, 3.425)	(1.646, 1.900, 2.156)	(2.625, 2.75, 2.875)	(2.152, 2.406, 2.667)	(1.778, 2.031, 2.286)	(1.653, 1.905, 2.161)	(1.538, 1.762, 2.056)	(1, 1, 1)

4.3 Geometric Means Value

Step 4: After completing the comparison matrix for the criteria, the geometric mean of fuzzy comparison values of each criterion has been calculated using Equation 4. For example, calculating the values of geometric means of fuzzy ($\tilde{r}_i$) of stock management (C1).

$\tilde{r}_i$ = [(1 x 3.528 x 2.087 x 2.795 x 1.424 x 2.778 x 1.313 x 0.451 x 3.034 x 2.046)] $^{1/10}$ =**1.768**

Table 5: Geometric Means of Fuzzy Comparison Values

Criteria		t	
C1	**1.768**	1.946	2.123
C2	1.115	1.213	1.316
C3	1.116	1.220	1.310
C4	1.293	1.423	1.539
C5	1.299	1.398	1.499
C6	1.769	1.956	2.140
C7	2.579	2.844	3.116
C8	2.414	2.619	2.818
C9	1.991	2.232	2.472
C10	2.042	2.258	2.461
Total	17.214	19.109	20.794
Reverse power -1	0.0581	0.0523	0.0481
Increase	0.0481	0.0523	0.0581

The geometric means fuzzy comparison values for all criteria are shown in Table 5. The total values and the reverse values are also presented in this particular table. Next, the relative fuzzy weight value (
0) of CV1 is calculated using Equation 5 as follows:

u= (1.768 x 0.0481); (1.946 x 0.0523); 2.123 x 0.0581)

= (**0.085; 0.102; 0.123**)

Further detailed information of the relative fuzzy weight values of all criteria is summarized in Table 6.

Table 6: Relative Fuzzy Weight Value

Criteria		O	
C1	**0.085**	**0.102**	**0.123**
C2	0.054	0.064	0.076
C3	0.054	0.063	0.076
C4	0.062	0.074	0.089
C5	0.062	0.073	0.087
C6	0.085	0.102	0.124
C7	0.124	0.149	0.181
C8	0.116	0.137	0.164
C9	0.096	0.117	0.144
C10	0.098	0.118	0.143

Then, the relative non-fuzzy weight of each criterion (. is calculating according the average of fuzzy weight value of each criterion using Equation 6. By incorporating the total of non-fuzzy weight value (4, the normalized weight value (e of each criterion is calculated using Equation 7 and has summarized as shown in Table 7.

u = (0.085+ 0.102+0.123) ÷ 3 = **0.103**

o = 0.103 ÷ 1.013 = **0.102**

Table 7: Average and Normalized Relative Weight of Criteria

Criteria		a	Rank
C1	0.103	0.102	5
C2	0.065	0.064	8
C3	0.064	0.063	9
C4	0.075	0.074	6
C5	0.074	0.073	7
C6	0.103	0.102	5
C7	0.151	0.150	1
C8	0.139	0.138	2
C9	0.119	0.118	4
C10	0.120	0.119	3
Total	1.013		

The priority of the criteria are recorded and analysed by using FAHP to find out which criterion have given negative impact to the warehouse operations efficiency. As Table 7 shows the ten criteria been ranked accordingly to the average and normalized relative weight. There are four main indicators been found directly affecting the warehouse operation referring to their normalized averaged weight as follows (i) Equipment (0.150), (ii) Environmental Concern (0.138), (iii) Special Handling Consideration (0.119) and (iv) Human Factor (0.118). Consequently, these four main criteria are the most important in warehouse operation efficiency that need more attention to operate and cater properly. In other words, when fail to perform these main criteria will directly affecting to the failure of warehouse operation efficiency.

5. Discussion and Recommendations

There are four main failure factors that affecting the warehouse operations, such as the condition of the equipment, poor environment condition, poor handling of special consideration and labour with insufficient knowledge or experience as shown in Table 8.

The movement of goods in the warehouse can run efficiency by using the right equipment for loading and unloading process. The typical characteristic of the goods to handled also a constraint for the operator to handle the different size and weight. It needs the proper forklift or equipment to move the goods which are normally palletization and loose cargo. The concern on equipment condition is very crucial since it will contribute to the failure of warehouse operation efficiency. This can be supported by a previous research mention that material handling equipment has positive contribution to the performance of warehouse operation (Frazelle, 2001). The equipment and machinery including forklift, conveyors, pallets jacks, hand trucks, and service carts need proper and frequent inspection by following the maintenance schedule including the tires. Hence, material handling and machinery shall be under control and good maintenance to perfectly perform the operation without fail (Karim et al., 2018). By using the hazardous condition equipment will make it unsafe to operate and disrupt the efficiency of operation that affecting to the delay in cargo delivery and the warehouse floor space will be congested.

Table 8: The Failure Factors of Warehouse Operations

Failure factors	Factors	Risk	Recommendation
Condition of the equipment	• Inefficiency of forklift • Machine breakdown	• Delay in cargo delivery • Congested	• Frequently inspection of equipment • Follow the schedule of repair
Poor environmental condition	• Natural disaster • Environment of work place • Environment condition	• Interrupting of operation • Damage of cargo and to warehouse facilities	• Briefing of awareness that impact to goods • Advising of labor • Practice good housekeeping
Poor handling of special consideration	• lack of skill and knowledge	• Interrupting warehouse operations • Damage of goods	• Training and guides • Advance planning
Labor with insufficient knowledge / experience	• Lack of skill and knowledge • Inefficient shift work schedule	• Inaccurate information / data record • Management of delivery schedule inaccurate • Inaccuracy inventory management	• Training • Seminar on workflow • Adoption of new technology to reduce human errors

Environment concern is very important because it showed the condition of environment especially it relates to employees, health and safety in the company. The failure factors contribute to the warehouse operation is due to poor environmental condition. This is because the environment of warehouse gives impact to the efficiency of warehouse activities which is to organize or planning the goods to be stored by order of the most frequent sales or stock grouped order without polluted or damaged. Therefore, the company shall consider good housekeeping practice. Disorder and untidiness in the warehouse will increase the certainty to many accidents, material damages, mixed merchandise and unpleasant work place. However, when it comes to natural disaster one of the environmental risk factor is the risk that cannot be predictable. Hence, to avoid from any unpredictable natural disaster is unachievable target to achieve by any companies.

Poor handling of special consideration is the third main failure factors that affecting warehouse operation efficiency. Due to the different size and function of equipment to handle special cargo such as heavy lifting cargo, fragile cargo, oversized cargo and perishable cargo. This special handling consideration shall be handling by skillful and knowledgeable labor following to the steps and procedures to avoid damage of goods. Lam et al. (2015) briefly mentioned that product characteristics irregularly impose uncertainties and limitation in warehouse operations planning. In other words, the warehouse manager shall be informed and aware of the type of goods coming to the warehouse and advanced planning shall be prepared before the goods reach at the receiving docks to avoid the delay during unloading time with proper special handling of the cargo.

Lastly, the factors that contribute to of warehouse operation efficiency are lack of skills, knowledge and experience of labor and inefficient shift work schedule resulting to fatigue. Those reasons will lead to inadequate information of the goods transfer, poor handling of equipment and machinery, and miscommunication among operators and customer service coordinator. In order to tackle the issues of human factor, it is very crucial to educate them through seminars and workshops on logistics and supply chain for better understanding the traditional warehouse operation practice of the company. Moreover, in the era to of Industrial Revolution 4.0, the company shall consider adopting the new technology in the market such as Scan, Barcode, and RFID to reduce human errors. The company shall consider carrying out training for the operators especially forklift drivers and operators handling machinery and equipment. Karim et. al (2018) mentioned that company should provide labor with professional certification especially on Occupational Health and Safety Assessment Series (OHSAS), International Organization for Standardization (ISO), Work Health & Safety (WHS/OHS) or OSHE, and industrial hygiene. By understanding the source of labor in the company, it will contribute to eliminating human errors at all level of the company.

6. Conclusions

As conclusion, warehouse industry plays its very crucial role in supply chain management. The efficiency of warehouse operation without fail and delay despite meeting customer satisfaction will upper grade the overall logistics services. Through this research, the objective of this study has been successfully achieved to determine these main failure factors 'equipment', 'environmental condition', 'special handling consideration' and 'labor factor'. Throughout the discussion and recommendation part of this study able to assist the upper management or decision maker of warehouse industry in identifying the failures factors that disrupting their warehouse operations efficiency. By acknowledging the priority and problematic area of failure indicators, the management level of warehousing company may consider recommendation of this study as action to be taken in order to improve the efficiency of warehouse operations in future. Moreover, this study contributes to the enhancement of warehouse study to provide more information, ideas, knowledge and references to the researchers or industry about the warehouse operations. For future research, the total number of respondents can be increased to obtain more information and the accuracy of the data collection for this research scope. Not only that, a deeper research on risk management of warehouse operation shall be conducted in the future research as well.

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