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The Efficacy of Hazardous Warehouse Operators is Influenced by Various Factors in Warehouse Operations

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Abstract. This exploratory research project investigates the factors affecting operations in hazardous warehouses and their impact on the efficiency of warehouse operators, utilizing data acquired via questionnaires. The sample group comprised 400 hazardous warehouse operators. Data analysis utilized descriptive statistics, encompassing frequency distribution, percentage, arithmetic mean, and standard deviation. Inferential statistics were employed, encompassing Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM). The researcher evaluated the model fit to verify its alignment with actual data. The metrics employed to assess the model's alignment with empirical data comprised Chi-Square = 1.295, CMIN/df = 1.295, CFI = 0.999, GFI = 0.988, IFI = 0.999, NFI = 0.996, AGFI = 0.952, RMSEA = 0.007, and RMR = 0.027. The factors associated with the storage of hazardous materials, concerning location and handling equipment, exert a direct positive impact on the safety measures for transporting hazardous materials, accounting for 48.0% of the influence on these safety measures, with a path coefficient of 0.98, statistically significant at 0.05. The factors associated with the transportation of hazardous materials, regarding measures and safety for the delivery of goods, exert a direct positive impact on the safety protocols for transporting hazardous materials, accounting for 48.0% of the variance in safety measures, with a path coefficient of 0.78, statistically significant at 0.001. The criteria for evaluating model fit were analyzed using statistical software.

Keywords: Hazardous Warehouse, Efficiency, Operations

1. Introduction

In a period of ongoing economic and industrial expansion, the management of hazardous warehouses is essential for improving the effectiveness of logistics and supply chain systems. Due to the significant hazards these commodities present to the environment and personal safety, operations in hazardous warehouses necessitate stringent regulations and procedures. To guarantee safety and mitigate any harm, it is essential to evaluate pertinent elements such as effective resource management, compliance with international safety standards, and the utilization of technology in system management. Consequently, examining the elements influencing operations in hazardous warehouses is crucial, particularly with the enhancement of operator efficiency, including resource management, technological implementation, and adherence to legal standards. Comprehending these elements will assist operators in formulating efficient operating plans and effectively minimizing costs.

Hazardous substances denote a range of chemicals or materials that may threaten humans, animals, plants, the environment, and property. Hazardous substances can be categorized according to the type of threat they present, including explosives, combustible materials, oxidizers, poisonous agents, infectious agents, radioactive substances, corrosives, and mutagens, as defined by the Hazardous Substances Act. Professor In 1992, hazardous compounds were categorized into four classifications according to the level of regulation.

Type 1: hazardous compounds - No authorization necessary, however adherence to general regulations is mandatory.
Type 2: hazardous compounds necessitate authorization for manufacturing or importation, and adherence to laws is mandatory.
Type 3: hazardous compounds necessitate authorization at each phase, including manufacturing, importation, exportation, or possession.
Type 4: hazardous substances - Prohibited from manufacturing, importation, exportation, or possession under any circumstances.

This research seeks to examine and evaluate the causal factors influencing the efficiency of hazardous warehouse operators and to assess the elements affecting operations within hazardous warehouses. This includes safety evaluations, logistical planning, and management enhancement. The objective is to assist operators in optimizing work processes, mitigating hazards, and augmenting competitive capability in the market. Empirical data will be utilized to produce a model applicable in the industrial sector, enhancing the advancement of logistics systems in the future.

2. Literature Review

2.1. Warehouse operations involving hazardous materials

Warehouse operations involving hazardous materials require careful management to ensure safety and efficiency. Implementation of safety management systems, such as ISO 45001, can significantly reduce accidents in hazardous warehouses (Ayuthaya et al., 2016). Selecting appropriate warehouses for hazardous materials is crucial and can be approached as a multiple criteria decision problem (Fýrat Sezer et al., 2016). In developing countries, there's often a gap between traditional and modern warehousing practices, with many facilities lacking basic mechanical equipment and automation (Dza & Kyeremeh et al., 2018). Proper manual material handling techniques are essential for worker safety, as demonstrated by the NIOSH lifting equation, which can assess and improve lifting practices to reduce musculoskeletal disorders among warehouse workers (Amaya Flocerfida et al., 2019). Factors such as age and length of employment can significantly impact workers' lifting capacity and safety, highlighting the need for tailored safety procedures and guidelines in warehouse operations (Amaya Flocerfida et

al., 2019) The efficacy of hazardous warehouse operators is influenced by various factors in warehouse operations (Zhang et al., 2020) propose a waterfall mechanism and three-stage model that consider cost, efficiency, and safety factors to improve dangerous goods warehouse operations (Benson, C., Obasi, I. C., Akinwande, D. V., & Ile, C. et al., 2024) emphasize the importance of implementing safety management systems, such as ISO 45001, to reduce accidents in hazardous warehouses. Their study shows that operator familiarity with management manuals and safety training contributes to decreased accidents (Ayuthaya et al., 2024) highlights the impact of both human and technological factors on warehouse productivity, emphasizing the importance of operator skill sets and optimized Warehouse Management Systems. The study identifies correlations among various factors affecting warehouse productivity through factor analysis. Collectively, these studies underscore the significance of safety protocols, efficient operational models, and the interplay between human skills and technological systems in enhancing the efficacy of hazardous warehouse operations.

2.2. Warehouse efficiency and safety in hazardous materials handling

Warehouse efficiency and safety in hazardous materials handling are influenced by several key factors. Layout planning, including distance optimization for forklifts and proper spacing between goods, impacts both operational efficiency and safety (Zhang et al., 2020). Implementing effective Warehouse Management Systems (WMS) and product slotting techniques can enhance overall warehouse performance (Vedaste, R., & Muiruri, P. M. et al., 2021). Safety management systems focusing on occupational health, working environment, and organizational context requirements are crucial for reducing accidents in hazardous warehouses (Benson, C., Obasi, I. C., Akinwande, D. V., & Ile, C. et al., 2024). Continuous monitoring, measurement, and improvement processes contribute to decreased accident rates (Benson, C., Obasi, I. C., Akinwande, D. V., & Ile, C. et al., 2024). Additionally, understanding and addressing various hazards that may affect warehouse processes is essential for maintaining safety (Lach, J., Szymonik, A., & Ociepa-Kubicka, A. et al., 2018). Training operators in safety techniques for handling hazardous materials and familiarizing them with management manuals can significantly improve proficiency and reduce accidents in hazardous warehouse operations (Benson, C., Obasi, I. C., Akinwande, D. V., & Ile, C. et al., 2024). In the burgeoning field of supply chain (SC) management at the beginning of the twenty-first century, many predictions have been made to determine the state of the fundamental concepts in the field, as well as stimulate debate, help guide resource allocation and implementation initiatives, and initiate research to improve many of the revolutionary topics in the understanding of SC management (Burinskienė, A., & Lingaitienė, O. 2023).

2.3. Instruction and Expertise Training

Instruction and Expertise Training is a critical determinant that directly influences the efficacy of hazardous substance warehouses. Numerous studies indicate that efficient training programs can assist employees in managing hazardous materials safely and enhance their performance (Reid, A. M., Brown, J. M., Smith, J. M., Cope, A. C., & Jamieson, S. et al., 2018). This study demonstrated that a training program centered on hazardous chemical management effectively diminished accidents and enhanced work performance (Pandey, N., Murugesan, K., & Thomas, H. R. et al., 2017). Emphasize that training and adherence to safety regulations are crucial for preventing accidents associated with the management of hazardous materials in warehouses (Dyer, T., Dillard, L., Harrison, M., Morgan, T. N., Tappouni, R., Malik, Q., & Rasalingham, S. et al., 2021). Training centered on hazardous substance management and occupational safety can enhance performance and mitigate risks in a warehouse containing hazardous materials.

2.4. Occupational Safety and Work Environment

Occupational Safety and Work Environment Ensuring safety in hazardous material warehouses is essential for effective operations. Numerous studies indicate that a secure environment and adherence to safety regulations can mitigate risk and enhance productivity (Usmani, S. Z., Schjesvold, F., Oriol,

A., Karlin, L., Cavo, M., Rifkin, R. M., ... & Houck, W. et al., 2019). This research determined that organizational safety culture affects performance in a hazardous materials warehouse (Phung, C., Vezina, B., Anwar, A., Wilson, T., Scott, P. C., Moore, R. J., & Van, T. T. H. et al., 2020). Utilizing technology to oversee hazardous items in warehouses, including automated monitoring systems and toxicity detection instruments, mitigates risk and enhances efficiency (Davis, A. P., Grondin, C. J., Johnson, R. J., Sciaky, D., Wiegers, J., Wiegers, T. C., & Mattingly, C. J. et al., 2021). This study demonstrated that safety compliance positively influences performance in a hazardous materials warehouse.

2.5. Psychological and behavioural determinants

The psychological states of workers, including stress and exhaustion, might influence job performance. Research indicates that stress management and psychological support can enhance work performance in a hazardous materials warehouse (Yan, X., Liu, Z., Zhang, Q., Lopez, J., Wang, H. et al., 2018). Employee weariness in a hazardous materials warehouse impairs performance and may result in accidents. (Chen, L., Carlton Jones, A. L., Mair, G., Patel, R., Gontsarova, A., Ganesalingam, et al., 2018). Psychological factors, including stress and anxiety, can influence safety behaviour's in a hazardous materials warehouse (Reynolds, C. J., Swadling, L., Gibbons, J. M., Pade, C., Jensen, M. P., Diniz, M. O., & Boyton, R. J. et al., 2020). This study determined that the management of workload and cognitive load can diminish work errors and enhance job performance.

2.6. Technological Advancements in Warehouse Operations

The implementation of advanced technologies in hazardous material storage facilities can enhance precision and mitigate occupational hazards. Automation and control systems can enhance operational efficiency and minimize direct exposure to dangerous substances (Jackson, S. J., Agada, S., Reynolds, C. A., & Krevor, S. et al., 2018). Utilizing technology for risk management and training cantered on contemporary technologies can enhance operational efficiency in hazardous material warehouses (Khan, A. et al., 2023). Contemporary technology, including automation and hazardous material surveillance, enhance safety and operational efficiency. This study examines the literature on determinants influencing worker performance in hazardous material warehouses, encompassing training, safety, psychological variables, and the implementation of current technologies in operations. The analysis indicates that these elements substantially enhance labour efficiency and mitigate the dangers linked to handling hazardous chemicals. Blockchain technology has introduced significant enhancements in financial services, providing distinctive methods to increase efficiency, security, and transparency in this sector (Sharma, P., & Karki, D. (2025).

3. Research Methodology

This research seeks to examine the factors influencing operations in hazardous warehouses and evaluate their impact on the efficiency of operators in the hazardous warehouse sector, which is essential for mitigating safety and environmental hazards. The variables encompass operational procedures, safety management systems, people competencies, and adherence to diverse legislation and standards. This research involved collecting data from hazardous warehouse operators in specific locations to assess the impact of these factors on efficiency and to formulate a more effective management model. This research enhances the comprehension of hazardous warehouse management, a critical factor that can mitigate risks and bolster the sustainability of business operations for industry operators.

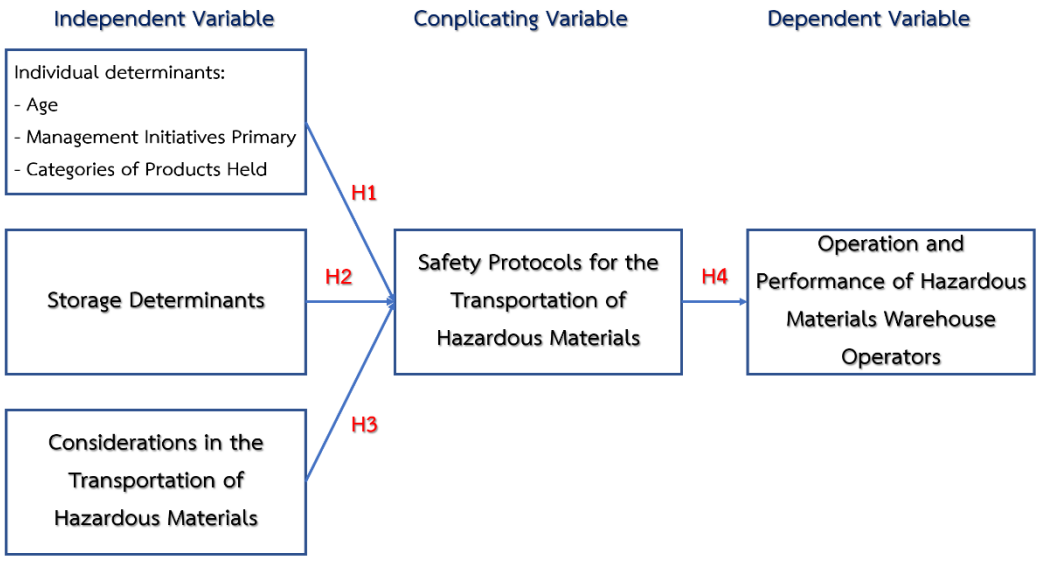

Fig. 1: Conceptual Framework of the efficacy of hazardous warehouse operators is influenced by various factors in warehouse operations.

This study employed a mixed-methods approach, incorporating both qualitative and quantitative research, executed in the following stages1

1. Analysis and design of hazardous storage facilities in duty-free zones

2. Type of research

3. Demographic and qualitative sample Data gathering in qualitative study involved conducting in-depth interviews with a sample of seven experts, professionals, and logistics academics. Their categorization was based on the nature and ratio of hazardous materials transportation and storage services, which included: Domestic and international road freight and distribution, sea freight forwarding, air freight forwarding, shipping and customs, hazardous materials warehousing, value-added services, and logistics consulting services.

4. Demographic and quantitative sample This study encompasses quantitative research to gather data on factors influencing the efficiency and operations of hazardous warehouse operators, as well as qualitative research, which is separated into two segments: Part 1 examines the factors influencing the efficiency and operations of hazardous warehouse operators, serving as a case study in this research. Part 2 comprises certified experts and academics specializing in logistics and hazardous warehouses, encompassing professionals from both the public and private sectors.

5. Qualitative research tools

6. Instruments for quantitative research Characteristics of the instrument The instruments employed for data collection this time are categorized into three sections as follows: Part 1 comprises a basic information questionnaire focused on personal aspects; Part 2 inquiries about safety protocols in the transportation of hazardous items; and Part 3 solicits insights about the broader context and the factors/needs deemed significant by service users, along with their recommendations.

7. Collection and analysis of qualitative data the researcher will compose a report detailing the outcomes of the qualitative research in a descriptive fashion for each case. The researcher will examine the data content and employ the conceptual framework together with relevant theories to interpret the responses gathered from the interview. In this subsequent section, the researcher executed the study in two formats: 1. Comprehensive interviews with a sample cohort of hazardous materials transportation and storage service providers from various enterprises or organizations. The procedure of documenting diverse details post-interview and aggregating all information as case data for each sample group. 2. Conduct interviews with key informants by transcribing the recorded interviews and verifying the

material through comprehensive reading in conjunction with repeated auditory review of the recordings. The acquired content will be forwarded to specialists for re-evaluation prior to its inclusion in the research report. The report will be organized based on the questions, reflecting the notions of each individual's responses.

8. The researcher analysed the quantitative data by doing the following steps: 1. Data preparation: The researcher assessed the absence of data to determine whether it was missing randomly or systematically. 2. Evaluated the fundamental statistical metrics of the sample. To ascertain the distribution characteristics of the sample group through descriptive statistics, encompassing frequency and percentage for categorical variables, and to analyse fundamental statistics, including mean, standard deviation (S.D.), coefficient of variation (C.V.), skewness, kurtosis, minimum (Min), and maximum (Max) for metric variables. The investigation to verify the preliminary agreement of the statistical analysis (Vongsirimas, N., Sitthimongkol, Y., Beeber, L. S., Wiratchai, N., & Sangon, S. et al., 2009) involves assessing kurtosis (extremes or outliers) through the construction of a Box Plot and a Scatter Plot diagram. Assessing the distribution properties of variables exhibiting normal curves (Normality) with the Kolmogorov-Smirnov Test. Examining the linear correlation between variables through the construction of a scatter plot diagram.

9. Analysis of quantitative data Conduct an analysis to address the objectives, evaluate the correlation coefficient among observed variables, and construct a correlation matrix. Develop a structural equation model, investigate the causal relationship of metric variables with loyalty through multiple regression analysis and hierarchical stepwise multiple regression analysis. Assess and validate the causal relationship model in accordance with the hypothesis, and compare the magnitude of the influence of causal factor variables on the dependent variable within the causal relationship model.

4. Research Findings

4.1. Sample Characteristics

This research investigation examines the aspects in warehouse operations that influence the efficiency of hazardous material operators. The findings were gathered from a questionnaire administered to a sample of 400 hazardous warehouse operators. The data were examined utilizing descriptive statistics, frequency distribution with percentages, arithmetic mean, standard deviation, and inferential statistics. The analysis employs Confirmatory Factor Analysis (CFA) and Structural Equation Modeming (SEM). The research model was evaluated for fit by assessing its congruence with actual data. The indices employed to evaluate the model's consistency with empirical data comprised the Chi-Square index, CMIN/df, CFI, GFI, IFI, NFI, AGFI, RMSEA, and RMR. The criteria for evaluating the model's consistency were analysed using pre-existing statistical software. The findings of the data analysis and interpretation were displayed in tables accompanied by explanations. The research findings can be delineated into six components as follows. Table 1 presents the findings from the analysis of general information regarding the sample organization, encompassing the characteristics of the entrepreneurs, the company's management structure, and the primary categories of products stored in the hazardous warehouse. The outcomes of the analysis are as follows.

Table 1: Displays the quantity and proportion of general information.

Overview of the organization		Quantity	Percentage
Traits of Entrepreneurs	Warehouse Operator	41	10.25
	Freight Forwarder	108	27.00
	Import	165	41.25
	Export	69	17.25
	Other entrepreneurs	17	4.25

Organizational framework of the company	Thai entrepreneurs hold 100.00% of the shares.	137	34.25
	Thai entrepreneurs hold more shares than foreign entrepreneurs.	146	36.50
	Foreign entrepreneurs hold more shares than Thai entrepreneurs.	81	20.25
	Foreign entrepreneurs hold 100.00% of the shares.	36	9.00
Primary categories of commodities housed in hazardous storage facilities	Explosives, flammable solids, substances prone to spontaneous combustion, substances which when wet emit flammable gases.	97	24.25
	Flammable gas, compressed gas, toxic gas, flammable liquid, oxidizing agent, organic substance	115	28.75
	Toxic, infectious, miscellaneous and environmentally hazardous substances	85	21.25
	Radioactive, corrosive substances	75	18.75
	Others	28	7.00
	Total	**400**	**100.00**

The examination of aggregate data from a sample of 400 individuals regarding entrepreneurship revealed that importers constituted the largest group, comprising 165 individuals, or 41.25 percent. This was followed by freight forwarders, totalling 108 individuals, or 27.00 percent; exporters, numbering 69 individuals, or 17.25 percent; a minority of warehouse operators, with 41 individuals, or 10.25 percent; and the smallest group, other operators, at 17 individuals, or 4.25 percent. The analysis of the company's management structure revealed that Thai entrepreneurs possessed a greater number of shares than their foreign counterparts, with a maximum of 146 individuals, representing 36.50 percent, followed by 137 individuals, or 34.25 percent, who held 100.00 percent of the shares. A minority of foreign entrepreneurs possessed a greater number of shares than Thai entrepreneurs, totalling 81 individuals, or 20.25 percent, being the lowest proportion. Foreign entrepreneurs possess 100.00% of the shares, comprising 36 individuals, or 9.00 percent. The predominant categories of goods stored in hazardous warehouses include flammable gases, compressed gases, toxic gases, and flammable liquids, totalling 115 individuals, or 28.75 percent. This is followed by explosives, flammable solids, self-igniting substances, and substances that emit flammable gases upon contact with water, accounting for 97 individuals, or 24.25 percent. Toxic substances, infectious substances, miscellaneous hazardous substances, and environmental hazards involve 85 individuals, or 21.25 percent. A minority consists of radioactive substances and corrosive substances, totalling 75 individuals, or 18.75 percent, while others comprise the least, with 28 individuals, or 7.00 percent, respectively. Factors that influence the storage and transportation of hazardous materials This section presents the findings of the analysis of factors that influence the storage and transportation of hazardous materials. This includes the location and apparatus used for material handling in the storage of goods, the steps and services involved in the storage of goods, and the safety measures and procedures for the storage of goods. The analysis yielded the following results:

Table 2: Determinants Factors that influence the storage and transportation of hazardous materials

Factors that influence the storage and transportation of hazardous materials		$\bar{x}$	**SD.**	**Value**
In terms of location and equipment for material handling in storage		**4.01**	**0.72**	**High**
STOR1	Availability and adequacy of storage facilities	4.00	0.81	High

STOR2	Product maintenance management system	4.06	0.75	High
STOR3	Tools and equipment for transporting materials within the storage area	4.01	0.91	High
STOR4	Modernization of material handling equipment	3.95	0.96	High
STOR5	Availability and adequacy of packaging used to pack goods during storage	4.02	0.90	High
In terms of product storage procedures and services		**3.95**	**0.82**	**High**
STOR6	Convenience and speed in contacting for pick-up and storage services and product placement areas	3.94	0.91	High
STOR7	Convenience and speed in the process of receiving, storing and storing products	3.75	0.95	High
STOR8	Accuracy and speed in using the receiving-storage service and product placement area	3.91	0.92	High
STOR9	Convenience and speed in procedures and formalities in the customs process	4.02	0.98	High
STOR10	Cost of receiving-storage services and product placement space	4.14	0.78	High
In terms of measures and safety in storing goods		**4.08**	**0.76**	**High**
STOR11	Contingency plans for emergencies and potential hazards	4.18	0.86	High
STOR12	Security of storage of goods	3.98	0.85	High
STOR13	Providing services in the area of insurance for possible damages	4.04	0.78	High
STOR14	Special precautions for product storage	4.12	0.81	High
The overall average		**4.01**	**0.69**	**High**

The research indicated that the parameters related to the storage and transportation of hazardous materials were deemed highly significant, with a mean of 4.01 and a standard deviation of 0.69. In every element, paramount priority was assigned to precautions and safety in the storage of commodities. The method and service of goods storage are regarded with significant importance, evidenced by an average score of 3.95 and a standard deviation of 0.82, indicating a high level of emphasis. The average cost of receiving and storage services, as well as the area for placing products, is 4.14. The measures and safety in storing items are assigned significant importance, reflected by an average of 4.08 and a standard deviation of 0.76, indicating a high level of priority. The average rating for the precautions and contingency plans addressing crises and potential hazards is 4.18. Dangerous Goods Transport Factors The analysis of factors affecting the transportation of dangerous goods, such as the vehicle used for delivery, the steps and services involved in the delivery process, and the safety measures and procedures in place to ensure the secure delivery of goods, is presented in this section. The results of the analysis are as follows.

Table 3: Determinates Factors in the transport of dangerous goods

Factors in the transport of dangerous goods		$\bar{x}$	**SD.**	**Value**
In terms of vehicles for delivering goods		**4.11**	**0.75**	**High**
TRAN1	Availability and adequacy of vehicles for delivering goods	4.16	0.93	High
TRAN2	Product Delivery Management System	4.17	0.93	High
TRAN3	Modernization of delivery vehicles	4.01	0.88	High
TRAN4	Availability and adequacy of packaging used to pack goods during delivery	4.10	0.77	High
In terms of product delivery procedures and services		**4.07**	**0.85**	**High**
TRAN5	Convenient and fast to contact for product/container delivery services	3.95	1.06	High
TRAN6	Convenient and fast in the delivery process of goods/containers	4.09	0.94	High

TRAN7	Accuracy and speed in using the delivery service of goods/containers	4.06	0.96	High
TRAN8	Delivery/Container Service Costs	4.18	0.96	High
In terms of measures and safety in product delivery		**4.05**	**0.74**	**High**
TRAN9	Contingency plans for emergencies and potential hazards	3.99	0.85	High
TRAN10	Security of product delivery	4.07	0.65	High
TRAN11	Providing services in the area of insurance for possible damages	4.08	0.83	High
TRAN12	Special precautions when delivering goods	4.08	0.91	High
The overall average		**4.08**	**0.72**	**High**

The analysis of the factors influencing risky products transportation revealed a significant importance, with a mean of 4.08 and a standard deviation of 0.72. In every area, paramount priority was assigned to the vehicle for transporting the cargo. The mode of transportation for the items was deemed highly significant, with an average score of 4.11 and a standard deviation of 0.75, while the delivery management system received the highest average score of 4.17. The procedures and services for goods delivery were prioritized, yielding an average score of 4.07 and a standard deviation of 0.85, with the delivery service costs per container receiving the highest average score of 4.18. The measures and safety for products delivery were prioritized, yielding an average of 4.05 and a standard deviation of 0.74. The highest rating was for the service ensuring potential damage and particular precautions during delivery, with an average of 4.08. Factors of safety measures in the transport of dangerous goods This section shows the results of the analysis of factors of safety measures in the transport of dangerous goods. The analysis results are as follows.

Table 4: Determinants Factors in safety measures for the transport of dangerous goods.

Factors in safety measures for the transport of dangerous goods		$\bar{x}$	**SD.**	**Value**
SAFE1	Operators have established safety measures for transportation.	4.11	0.91	High
SAFE2	The operator selects truck drivers to work.	4.37	0.83	Most
SAFE3	Working conditions and incentives that employers provide to truck drivers	4.36	0.86	Mort
SAFE4	Attitudes of truck operators towards transport measures	4.42	0.71	Most
The overall average		**4.31**	**0.75**	**Most**

The investigation of safety measures in the transport of hazardous materials revealed a significant emphasis, with an average score of 4.31 and a standard deviation of 0.75. Three aspects were prioritized, with the foremost being the attitude of truck operators towards transport measures, averaging 4.42. This was followed by the selection of truck drivers by operators at 4.37, working conditions and incentives provided to truck drivers at 4.36, and the establishment of transport safety measures by operators, which received a rating of 4.11. Performance of hazardous warehouse operators This section shows the results of the analysis of the performance of hazardous warehouse operators, including the aspects of capability, access to services, communication, and reliability. The analysis results are as follows.

Table 5: Determinants Operation and performance of hazardous warehouse operators

Operation and performance of hazardous warehouse operators		$\bar{x}$	**SD.**	**Value**
In terms of ability		**4.38**	**0.68**	**Most**
EFFI1	The company's vehicles used for transportation are of good standard.	4.23	0.71	Mort
EFFI2	The equipment and tools used for work are modern and ready for use.	4.40	0.82	Mort
EFFI3	The staff can deliver the goods to the destination on time.	4.41	0.83	Mort

EFFI4	Employees are able to use equipment to move goods correctly.	4.46	0.67	Mort
EFFI5	The staff are skilled in providing service and solving problems.	4.42	0.73	Mort
In terms of service access		**4.35**	**0.72**	**Most**
EFFI6	The company has a simple service process that makes it easy to understand the transportation service.	4.28	0.85	Mort
EFFI7	The company is located in a community, convenient for using the service.	4.16	0.86	High
EFFI8	The company provides services that can be accessed at any time.	4.38	0.82	Mort
EFFI9	Easy-to-understand shipping document formats	4.42	0.81	Mort
EFFI10	The staff are knowledgeable about the service formats and can provide information.	4.48	0.67	Mort
In terms of communication		**4.41**	**0.62**	**Most**
EFFI11	The staff is able to communicate with customers about service.	4.50	0.65	Mort
EFFI12	There are several ways to contact the company.	4.39	0.83	Mort
EFFI13	The company works systematically and has good communication and coordination.	4.26	0.75	Mort
EFFI14	The company has printed media to disseminate information to customers.	4.45	0.70	Mort
EFFI15	Customers can contact the company to check the information of the transported goods.	4.47	0.69	Mort
In terms of credibility		**4.42**	**0.67**	**Mort**
EFFI16	The company provides services that are credible in the eyes of customers.	4.44	0.70	Mort
EFFI17	The company delivers products in accordance with all contractual terms.	4.47	0.69	Mort
EFFI18	The company delivers products to the correct location and on time.	4.38	0.83	Mort
EFFI19	The company is well-known and well-established in the freight forwarding industry.	4.41	0.71	Mort
	The overall average	**4.39**	**0.64**	**Mort**

The research of hazardous warehouse operators revealed a peak efficiency level, averaging 4.39 with a standard deviation of 0.64, demonstrating exceptional reliability. Capability: The optimal level, exhibiting an average of 4.23 and a standard deviation of 0.68, with the best proficiency among personnel in utilizing equipment for the accurate movement of items, averaging 4.46. Service accessibility: The optimal level, with a mean of 4.35 and a standard deviation of 0.72, indicates that staff possess substantial understanding of service forms and can give information, reflected in a mean of 4.48. Communication: The most effective level, exhibiting an average of 4.41 and a standard deviation of 0.62, with the highest proficiency among staff in communicating with clients regarding service, averaging 4.50. Reliability: The optimal level, characterized by an average of 4.42 and a standard deviation of 0.67, with the highest tier of enterprises fulfilling all contractual obligations, averaging 4.47. Confirmatory factor analysis of the model of factors that influence the efficiency and performance of dangerous commodities warehouse operators This section evaluates the model's consistency by conducting a confirmatory factor analysis of the factors that influence the efficiency and performance of dangerous commodities warehouse operators. Factors of dangerous goods storage and transportation, factors of dangerous goods transportation, factors of dangerous goods transportation safety measures, and the dependent variable, efficiency of dangerous goods warehouse operators, comprise the variables employed in the analysis. which was employed to conduct a latent multi-factor confirmatory factor analysis (Multi Factor CFA Model) and employ the arrow-joining technique to compare the error values of two variables by taking into account the MI (Modification Indices) value.

The results are summarized in each aspect as follows: The efficiency and operations of dangerous products warehouse operators are influenced by the variables in the model. The model's consistency was verified through a confirmatory factor analysis in relation to the factors of storage and transportation of hazardous materials. The results of the confirmatory component model analysis were consistent with the empirical data at a high level, as evidenced by a Chi-Square value of 52.993, df = 43, Sig. = 0.141 > 0.05, and CMIN/df. = 1.232 < 5.0. The relative fit index (CFI) was 0.998 > 0.90, the fit index (GFI) was 0.982 > 0.90, the adjusted fit index (AGFI) was 0.956 > 0.80, and the root mean square error of approximation (RMSEA) was 0.024 < 0.05. The fit index, shown by the root mean square of the standardized residual (RMR), was 0.013, which is less than 0.05; the comparative fit index with the free model (NFI) was 0.990, beyond 0.90; and the comparative fit index with the base model (IFI) was 0.998, also surpassing 0.90, so satisfying all seven conditions. The model is well-aligned with the empirical data.

Table 6: Determinants Factors in the storage and transportation of dangerous goods

Factors in the storage and transportation of dangerous goods	λ	**SE.**	**t-value**	R^2	**AVE**	**CR.**
In terms of location and equipment for material handling in storage					0.663	0.906
STOR1	0.63	0.05	13.04**	39.30%		
STOR2	0.81	0.05	17.88**	64.90%		
STOR3	0.90	0.06	20.11**	80.40%		
STOR4	0.92	0.07	19.03**	84.30%		
STOR5 (Parameter constant)	0.79	-	-	62.50%		
In terms of product storage procedures and services					0.739	0.934
STOR6	0.81	0.06	19.18**	65.30%		
STOR7	0.85	0.07	18.73**	71.70%		
STOR8	0.87	0.06	21.39**	76.10%		
STOR9	0.93	0.05	26.77**	86.60%		
STOR10 (Parameter constant)	0.84			69.70%		
In terms of measures and safety in storing goods					0.896	0.972
STOR11	0.96	0.06	18.31**	91.90%		
STOR12	0.97	0.06	20.12**	94.80%		
STOR13	0.92	0.04	24.69**	84.00%		
STOR14 (Parameter constant)	0.94	-	-	87.60%		

The variables in the model assessing the efficiency and operations of hazardous materials warehouse operators, specifically the transportation of hazardous goods, were evaluated for model consistency through confirmatory factor analysis via a latent multi-factor analysis (Multi Factor CFA Model). The analysis results indicate a strong alignment with the empirical data, evidenced by Chi-Square = 31.549, df = 22, Sig. = 0.085 (> 0.05), and CMIN/df = 1.434 (< 5.0). The model demonstrates robust consistency and statistical significance, with the comparative fit index (CFI) at 0.998 (> 0.90), the goodness-of-fit index (GFI) at 0.987 (> 0.90), the adjusted goodness-of-fit index (AGFI) at 0.954 (> 0.80), the root mean square error of approximation (RMSEA) at 0.033 (< 0.05), the standardized root mean square residual (RMR) at 0.015 (< 0.05), the normed fit index (NFI) at 0.993 (> 0.90), and the incremental fit index (IFI) at 0.998 (> 0.90), thereby satisfying all seven criteria. The model aligns with the empirical data.

Table 7: Factors in the transport of dangerous goods

Factors in the transport of dangerous goods	λ	SE.	t-value	R^2	AVE	CR.
In terms of vehicles for delivering goods					0.654	0.883
TRAN1	0.81	0.10	14.15**	65.50%		
TRAN2	0.85	0.10	14.72**	71.50%		
TRAN3	0.87	0.09	15.91**	76.30%		
TRAN4 (Parameter constant)	0.69	-	-	48.10%		
In terms of product delivery procedures and services					0.736	0.917
TRAN5	0.76	0.07	15.00**	57.40%		
TRAN6	0.92	0.05	20.95**	84.80%		
TRAN7	0.91	0.05	22.18**	82.80%		
TRAN8 (Parameter constant)	0.83	-	-	69.40%		
In terms of measures and safety in product delivery					0.748	0.922
TRAN9	0.90	0.03	29.16**	81.20%		
TRAN10	0.76	0.03	19.84**	57.10%		
TRAN11	0.86	0.03	26.35**	74.50%		
TRAN12 (Parameter constant)	0.93	-	-	86.60%		

4.2. Factors of safety measures in the transport of dangerous goods.

Confirmatory factor analysis was employed to assess the model consistency of variables influencing the efficiency and operations of hazardous materials warehouse operators about safety measures for the transportation of dangerous items. The first-order confirmatory factor analysis (One Factor CFA Model) demonstrated a strong alignment with the empirical data, evidenced by Chi-Square = 0.372, df = 2, Sig. = 0.830 > 0.50, and CMIN/df = 0.186 < 5.0. It was consistent and had statistical values with the relative fit index (CFI) equal to 1.000 > 0.90, the fit index (GFI) equal to 1.000 > 0.90, the adjusted fit index (AGFI) equal to 0.998 > 0.80, the root mean square error of approximation (RMSEA) equal to 0.000 < 0.05, the fit index in the form of error or the square root mean square of the standardized residual (RMR) equal to 0.002 < 0.05, The comparative fit index with free model (NFI) was 1.000 > 0.90 and the comparative fit index with base model (IFI) was 1.001 > 0.90, which passed all 7 criteria. The safety measures model for hazardous materials transport aligns well with empirical evidence.

Table 8: Factors of safety measures in the transport of dangerous goods

Factors of safety measures in the transport of dangerous goods	λ	SE.	t-value	R^2	AVE	CR.
					0.775	0.931
SAFE1	0.70	0.06	17.05	95.40%		
SAFE2	0.98	0.04	33.25	87.40%		
SAFE3	0.94	0.04	30.15	78.40%		
SAFE4 (Parameter constant)	0.89	-	-	48.80%		

4.3. Performance of hazardous warehouse operators.

The variables influencing the efficiency and performance of hazardous warehouse operators were assessed for the model's consistency through confirmatory factor analysis. The latent multi-factor analysis (Multi Factor CFA Model) yielded results that aligned well with the empirical data, evidenced by a Chi-Square value of 80.087, degrees of freedom (df) of 61, and a significance level (Sig.) of 0.051, which is greater than 0.50. The CMIN/df ratio was 1.313, below the threshold of 5.0. Additionally, the model demonstrated strong consistency and statistical significance, with a comparative fit index (CFI) of 0.998, goodness-of-fit index (GFI) of 0.979, adjusted goodness-of-fit index (AGFI) of 0.935, root

mean square error of approximation (RMSEA) of 0.028, and root mean square of the standardized residual (RMR) of 0.009. The normed fit index (NFI) was 0.993, and the incremental fit index (IFI) was 0.998, both exceeding the 0.90 benchmark, thereby satisfying all seven criteria. The efficiency model of hazardous materials warehouse operators aligns with empirical evidence.

Table 9: Performance of hazardous warehouse operators

Performance of hazardous warehouse operators	λ	SE.	t-value	R^2	AVE	CR.
In terms of ability					0.784	0.947
EFFI1	0.67	0.05	15.88	44.70%		
EFFI2	0.95	0.04	31.18	91.00%		
EFFI3	0.98	0.04	33.33	95.50%		
EFFI4	0.92	0.02	42.91	84.30%		
EFFI5 (Parameter constant)	0.88	-	-	76.80%		
In terms of service access					0.799	0.952
EFFI6	0.86	0.05	21.89	73.80%		
EFFI7	0.76	0.06	18.80	58.10%		
EFFI8	0.93	0.04	34.56	86.20%		
EFFI9	0.97	0.03	41.18	94.50%		
EFFI10 (Parameter constant)	0.93	-	-	86.90%		
In terms of communication					0.669	0.909
EFFI11	0.88	0.04	23.04	77.50%		
EFFI12	0.91	0.05	25.01	82.20%		
EFFI13	0.69	0.05	16.64	46.90%		
EFFI14	0.76	0.04	26.48	56.90%		
EFFI15 (Parameter constant)	0.84	-	-	70.90%		
In terms of credibility					0.773	0.945
EFFI16	0.89	0.04	24.77	79.50%		
EFFI17	0.87	0.04	23.01	75.30%		
EFFI18	0.92	0.05	23.74	85.40%		
EFFI19 (Parameter constant)	0.87	-	-	75.70%		

4.4. Structural equation analysis of the model of factors that influence the efficacy and operation of hazardous warehouse operators.

This section analyses the structural equation model (System Equation Model: SEM) concerning the factors influencing the efficiency and operations of hazardous warehouse operators. The aim is to assess the model's appropriateness and accuracy, making necessary adjustments to ensure completeness and acceptable statistical values by integrating the Modification Indices variables. Additionally, the analysis evaluates the model's validity by examining variable weight values and R2 values to assess the covariation of the indicators.

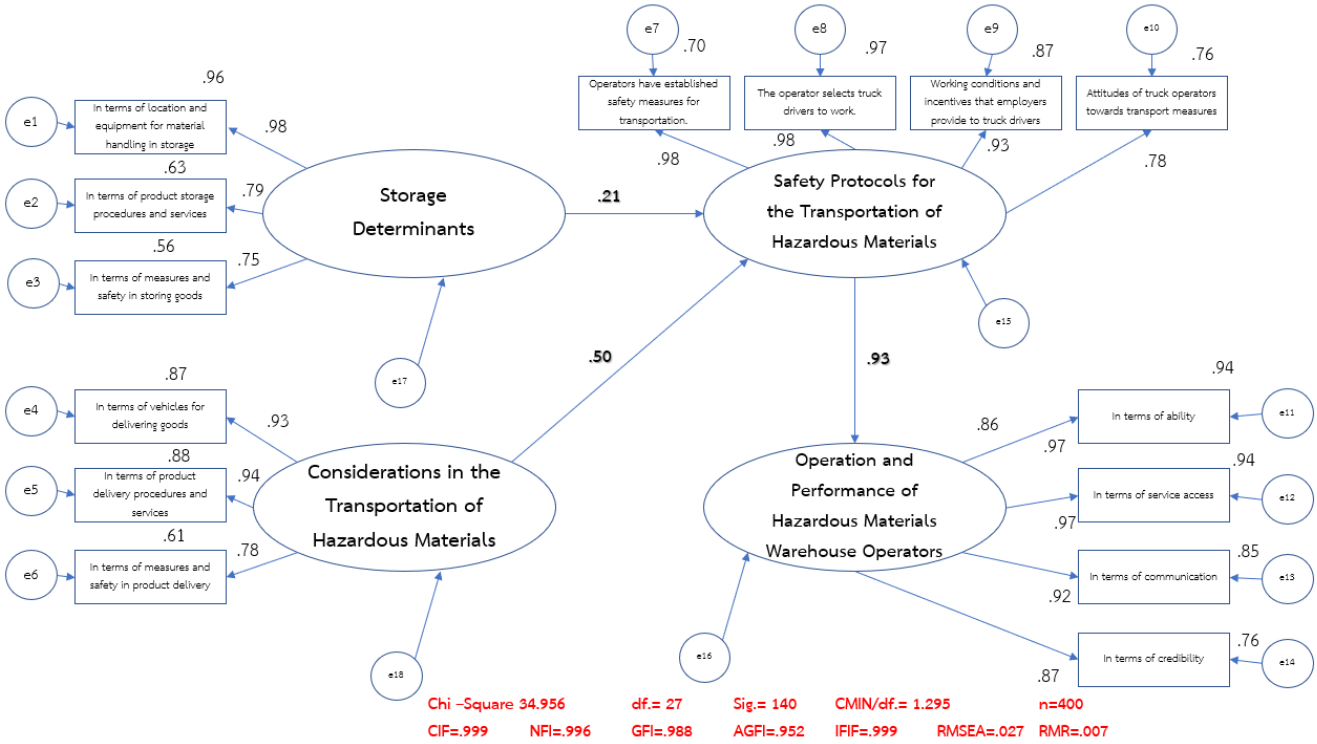

Fig 2: Structure Equation Modelling of the efficacy of hazardous warehouse operators is influenced by various factors in warehouse operations.

Table 10: Displays statistical metrics to evaluate the quality of the structural equation model for the elements influencing the efficiency and performance of hazardous warehouse operators.

Index	Criteria	Result	Conclusion	The notion of citation
Chi –Square	p. > 0.05	34.956	Meets	Hair et al. (1998;2006), Bollen et al. (1989) and Ayuthaya, V. I. N., Singhdong, P., & Weerapong, P. et al., (2025)
CMIN/df.	< 5.0	1.295	Meets	Bollen et al. (1989) , Diamantopoulos Siguaw (2000)
GFI	≥ 0.90	0.988	Meets	Hair et al. (1998;2006), Browne and Cudeck (1993)
AGFI	≥ 0.90	0.952	Meets	Durande-Moreau and Usunier (1999), Harrison walker (2001)
NFI	≥ 0.90	0.996	Meets	Hair et al. (1998;2006) , Mueller et al. (1997)
IFI	≥ 0.90	0.999	Meets	Hair et al. (1998;2006) , Mueller et al. (1997)
CFI	≥ 0.90	0.999	Meets	Hair et al. (1998;2006) , Mueller et al. (1997)
RMR	< 0.05	0.027	Meets	Diamantopoulos , Siguaw (2000)
RMSEA	< 0.05	0.007	Meets	Hair et al. (1998;2006), Browne and Cudeck (1993)

Table 11: Outcomes of structural equation modelling about the causal factors influencing the efficacy and functioning of hazardous warehouse operators.

Variable (Relationship Pair)			λ	SE.	t-value	Sig.	R^2
Factors of safety measures in the transport of dangerous goods	<--	Factors in the storage and transportation of dangerous goods	0.21	0.13	2.28	0.023*	48.00%
Factors of safety measures in the transport of dangerous goods	<--	Factors in the transport of dangerous goods	0.50	0.13	5.61	0.000**	48.00%
Performance of hazardous warehouse operators	<--	Factors of safety measures in the transport of dangerous goods	0.93	0.02	37.30	0.000**	86.00%

5. Discussion and Conclusion

The research on elements influencing the efficacy and operations of hazardous warehouse operators has the subsequent objectives. To examine the determinants influencing the efficacy and operations of hazardous warehouse operators. To assess the functioning of hazardous warehouses to ensure adherence to the rules and regulations of the Hazardous Substances Act or other pertinent legislation and to evaluate and formulate designs for hazardous warehouses within duty-free zones through a case study of a logistics firm. The research methodology employed a mixed methods approach, integrating quantitative and qualitative research. A survey was executed, and data was gathered from a questionnaire. The sample population consisted of 400 hazardous warehouse operators. The instrument's dependability was assessed using the Cronbach Alpha Formula with a sample size of 40. The instrument's reliability was assessed and found to be extremely dependable, with a test value of 0.977.

5.1. Discussion

From the research results, the examination of general data regarding the sample group's organizations revealed that the majority of entrepreneurs were importers, comprising 41.25 percent. Research findings indicate that the most significant factor influencing the efficiency and operations of hazardous materials warehouse operators is safety measures for the transport of dangerous goods. This is followed by the factors of dangerous goods transport and the storage and transport of hazardous materials, both of which are also deemed highly important, with a mean score of 4.01 and a standard deviation of 0.69. The significance of hazardous materials transportation is emphasized, with a mean of 4.08 and a standard deviation of 0.72. The vehicle for transporting products is deemed of utmost importance in every aspect. Safety procedures in the transportation of hazardous materials are prioritized, evidenced by a mean score of 4.31 and a standard deviation of 0.75. The research findings regarding the efficacy of hazardous warehouse operators indicated a peak efficiency, with a mean of 4.39 and a standard deviation of 0.64. The research findings about the confirmatory factor analysis of the model influencing the efficiency and operations of hazardous materials storage operators. The model aligns with the empirical data. The factor analysis results identified the factors related to the storage and transportation of hazardous materials. The outcomes of the confirmatory factor analysis align well with the empirical data. It comprises three latent variables: the location and apparatus for material handling in storage, the

processes and services involved in storage, and the measures and safety protocols in storage. The coefficient weight ranges from 0.63 to 0.97, exceeding 0.40, while the multiple correlation coefficient (R2) spans from 39.30% to 94.80%. The average variance extracted (AVE) ranges from 0.663 to 0.896, beyond 0.50, while the composite reliability (CR) spans from 0.906 to 0.972, surpassing 0.60. The findings from the structural equation model analysis regarding the factors influencing the efficiency and operations of hazardous warehouse operators indicated a strong alignment with empirical data. This is in accordance with the principles established by Hair et al. (1998; 2006), Bollen et al. (1989), and Ayuthaya, V. I. N., Singhdong, P., & Weerapong, P. et al., (2025). The evidenced by a Chi-Square value of 34.956, degrees of freedom of 27, significance level of 0.140 (greater than 0.05), and a CMIN/df ratio of 1.295 (less than 5.0). The determinants of storage and transportation of hazardous materials comprised three latent variables: the site and apparatus for material handling in storage, the procedures and services in storage, and the safety measures in storage, with regression coefficients ranging from 0.75 to 0.98. The storage and transportation factors of hazardous materials positively impacted the efficiency and operations of hazardous warehouse operators, evidenced by a regression coefficient of 0.21, and accounted for 48.00% of the structural equation explaining the factors influencing their efficiency and operations. The storage and transportation factors of hazardous materials positively and indirectly impacted the efficiency and operations of hazardous warehouse operators, mediated by safety measures in the transportation of dangerous goods, with a regression coefficient of the independent variable represented by standardized scores of 0.20. The factors associated with the transportation of hazardous materials comprise three latent variables: delivery vehicles for products, delivery methods and services, and safety precautions for goods delivery. The regression coefficient weights vary between 0.78 and 0.94. Transportation factors concerning hazardous materials positively and directly impact the efficiency and operations of hazardous products warehouse operators, with a regression coefficient of 0.50. The safety procedures for transporting hazardous materials comprise four latent variables: safety protocols, personnel selection, working environment and motivation, and entrepreneurs' attitudes towards transportation practices. The regression coefficient weights vary from 0.78 to 0.98. The test results indicate that safety measures in the transportation of hazardous materials significantly enhance the efficiency and operations of hazardous warehouse operators, evidenced by a regression coefficient of 0.93, which accounts for 86.00% of the structural equation explaining the factors influencing their efficiency and operations.

The research findings describe the hypothesis testing results of the elements influencing the efficiency and operations of hazardous warehouse operators as follows. Factors Pertaining to the Storage of Hazardous Materials The location and equipment for material handling in goods storage directly enhance safety measures for the transportation of hazardous materials. The impact on safety measures for the transport of hazardous materials is quantified at 48.0%, with a path coefficient of 0.98. Factors Pertaining to the Storage of Hazardous Materials Procedures and services in goods storage directly enhance safety measures for the transportation of hazardous materials. The impact on safety measures for the transportation of hazardous materials is quantified at 48.0%, with a path coefficient of 0.79. Factors associated with the storage of hazardous materials, concerning safety measures and storage protocols, exert a direct and beneficial impact on safety measures for the transportation of hazardous materials, accounting for 48.0% of the influence, with a path coefficient of 0.75. Factors associated with the transportation of hazardous materials, specifically regarding vehicles utilized for delivery, exert a direct and beneficial impact on safety protocols for the transport of dangerous goods, accounting for 48.0% of the variance in safety measures, with a path coefficient of 0.93. Factors associated with the transportation of hazardous materials, concerning the protocols and services for storage, exert a direct and beneficial impact on safety measures for the transport of dangerous goods, accounting for 48.0% of the variance in safety measures, with a path coefficient of 0.94. Factors affecting the transportation of hazardous materials regarding measures and safety in product delivery exert a direct and beneficial impact on safety protocols in the transport of dangerous goods, accounting

for 48.0% of the variance in safety measures, with a path coefficient of 0.78. Factors in the transportation of hazardous materials indicate that safety measures significantly enhance the operations and efficiency of hazardous products warehouse operators, accounting for an 86.0% influence on safety measures in the transport of hazardous materials, with a path coefficient of 0.93.

5.2. Conclusion

The research findings indicate that the parameters associated with the storage of hazardous materials exert a direct and beneficial impact on the safety protocols for moving such items, with the location and equipment utilized for material transport being the most influential elements. Priority must be assigned to the segregation of the transportation of multiple categories of hazardous materials, and this separation should adhere to the techniques and criteria established by applicable legislation. Moreover, drivers or personnel engaged in the transportation of hazardous materials should be incentivized to undergo training and have their attributes and qualifications assessed to guarantee preparedness for their responsibilities, as they will bear significant accountability for both property and environmental safety. The research findings indicate that elements related to the transportation of hazardous materials exert a direct and favourable impact on safety protocols, with measures and safety in the delivery of goods demonstrating the most significant beneficial influence. Consequently, emphasis must be placed on mitigating hazards in the event of emergencies or accidents occurring during transit. Consequently, a document should be established to instruct drivers on hazardous materials, to be prepared by producers, importers, exporters, and holders of dangerous commodities intended for transport. Documents can be generated from the safety data of substances, encompassing the following topics: name of hazardous materials, trade name, classification details for dangerous goods in transit, hazardous constituents, physical and chemical properties, fire and explosion data, health hazard information, safety precautions, and transportation and storage protocols. Furthermore, prior to establishing the route, it is imperative to analyze the itinerary and select a travel path that circumvents areas that could pose significant hazards in the case of an accident, such as tunnels adjacent to heavily populated areas and narrow roadways.

The research findings indicate that safety measures in the transportation of hazardous materials directly and positively impact the operations and efficiency of hazardous products warehouse operators. Consequently, it is imperative to assess vehicles for their appropriateness and safety in the transportation of hazardous materials. Suitable personal protective equipment must be supplied for vehicle operators and equipment to avert accidents resulting from spills or leaks of hazardous materials. Furthermore, the business must assume a pivotal role in addressing issues and devising strategies to avert accidents, ensuring their nonrecurrence. This necessitates the development of knowledge and comprehension among all operators about the safety of moving hazardous materials. A department must be established to monitor and evaluate the outcomes, and this process must be rigorously and consistently enforced to achieve measurable results. Subsequent research should investigate the causal elements influencing the efficiency and performance of hazardous materials warehouse operators, categorizing the models by business size and operator types, to enhance operational quality and management for optimal efficiency. The forthcoming study should investigate the causal factors influencing the efficiency and performance of hazardous warehouse operators by employing models derived from pertinent concepts and theories to formulate a research model aimed at optimizing efficiency, with the study's findings serving as a guideline for enhancing the performance of hazardous warehouse operators.

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