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Study of Air in a Vehicle Brake System by TOPSIS and EDAS Combining with FAHP

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Abstract: All vehicles are exported globally through sea freight, which involves extended storage periods and exposure to high temperatures. Consequently, issues with the brake system have been identified, arising from the presence of air and contaminants within the system. The aim is to minimize the number of Air in the Vehicle Brake System, targeting zero defects while eliminating repair and labor costs. Research integrating TOPSIS and EDAS with FAHP to address design and transportation issues in vehicles has not yet been identified. Through a systematic literature review, specialist questionnaires, and the Fuzzy Analytic Hierarchy Process (FAHP), the study identified the main contributing factors to the brake system issues and established their importance ranking. Based on this analysis, a multi-criteria framework for weights was determined using the FAHP comprehensive evaluation method. Subsequently, the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) method and The Evaluation based on Distance from Average Solution (EDAS) were employed to evaluate and classify the alternatives based on the obtained weights. By specifying a scoring guideline, the attributes of the brake system could be quantified, ensuring objectivity. Consequently, the brake system issue is implemented, verified, and analysed using TOPSIS and EDAS supported by FAHP. the priority ranking of 4 criteria levels and alternatives are calculated with P_i = 0.995, 0.690, and 0.574 respectively in the TOPSIS technique and AS_i = 0.796, 0.500, and 0.478 respectively in the EDAS technique. The total Rejection per thousand of Air in a Vehicle Brake System is 0.99 for C_{A1}, 0.12 for C_{A2}, and 0.03 for C_{A3}. The results highlight the effectiveness of integrating TOPSIS and EDAS with FAHP in reducing the presence of Air in the Vehicle Brake System and minimizing repair costs, with a primary focus on enhancing vehicle safety control as the most critical concern. Additionally, the research prioritizes assessing the risk associated with Air in the Vehicle Brake System.

Keywords: Topsis, Edas, Fahp, Air in a vehicle brake system, Organic coating, Inorganic coating.

1. Introduction

Thailand serves as a manufacturing base of numerous automobile brands to produce a wide range of passenger cars and commercial vehicles for both domestic using and global export. All vehicle exports are primarily transported by sea freight to seven continents [1] in Figure 1. With this sea freight transportation, it always leads to some issues in brake system such as the presence of Air and Contaminants since transportation period and high ambient temperature. These issues adversely affect the effective of braking control system, with the driver experiencing a soft brake pedal and a longer pedal travel [2], inhibiting the ability to stop the vehicle effectively. Consequently, this impacts the vehicle's control feature control systems [3], and it may surely be the causes of accidents. Generally, the vehicle braking system consists of various components of brake booster, brake master cylinder, brake fluid piping system, antilock braking module

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Figure. 1 Manufacturing Bases and Destinations [1]

and caliper brake [4]. After analysis of material properties and production processes, the testing results show that these air and contamination issues in the brake system occurring at the component of caliper brake. These air and contamination issues must be solved and repaired before delivering to customers, this is severe cause of cost addition for manufacturers.

This paper studies the presence of Air in a Vehicle Brake System by TOPSIS and EDAS Combined with FAHP. It provides a comparative analysis between the TOPSIS and EDAS techniques. The advantage of the TOPSIS technique lies in its widespread use as a multi-criteria decision-making method [5], offering benefits such as the ability to reflect human preferences and simplicity in computation. On the other hand, the EDAS technique offers high efficiency and requires less computational effort compared to other decision-making and classification methods [6]. Therefore, it was chosen for implementation in this research. Both techniques were applied, and their results were compared.

2. Problem statement

The undesirable Air and contaminants combine with the brake fluid in the Vehicle Brake System. The Air in the Vehicle Brake System problem affects vehicle hold per driver intent, vehicle stopping distance performance, and brake feature function. The air is generated in the vehicle brake system during sea freight's long storage time at high temperatures and high ambient conditions. The highlighted issue is vehicle's unable to stop and safety control is the critical concern. The purpose is to reduce vehicle number of Air in the Vehicle Brake System until it reaches zero defects, which is the cause of bubbles generated by the caliper brake under transportation uncertainties and multiple factors. The conventional technique is used in air manual bleeding without prioritizing, weighting, and ranking, resulting in unorganized and unmanaged processes, thus leading to uncontrolled issues and repair costs prior to vehicle delivery. Introducing the TOPSIS and EDAS techniques combined with FAHP addresses this issue by providing prioritization, weighting, and ranking capabilities. The expected outcomes include a reduction in vehicle defect rates and elimination of repair costs. The evaluation and validation of the Vehicle Brake System problem are conducted through 3 experiments as follows: 1) Measurement Air Volume in Brake System by Syringe, 2) Brake Pedal Travel Test, 3) Brake Stopping Distance Performance Test [7]. The clustering problem concerning by Ward's method. The vehicle sea freight Storage time 60 to 120 days and temperature 60 °C able to maximum gas generate. The brake

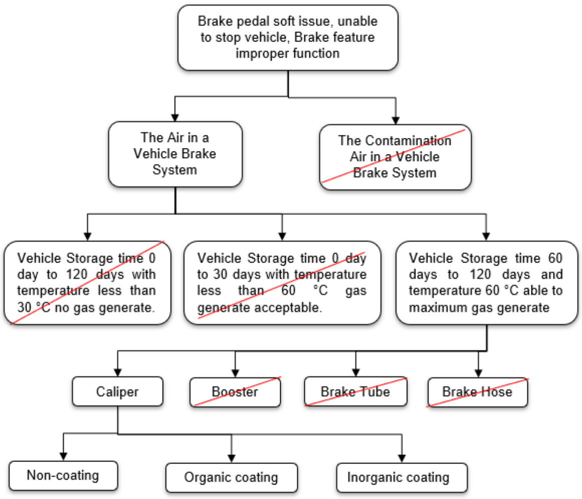

Figure. 2 The Drill Down Tree of Problem Statement

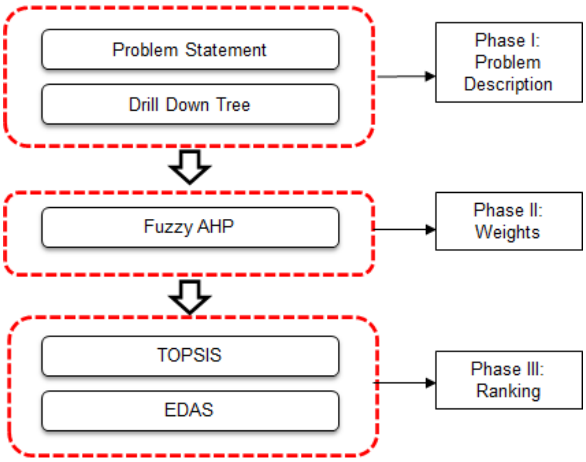

Figure. 3 The schematic structure of the proposed approach

caliper is the main component for generating gas [8]. The caliper coating type is affecting the occurrence of problems.

Drill Down Tree Analysis is a data analysis technique used to explore a data set in a hierarchical manner by gradually breaking down aggregated Multiple Items in Investigation. This technique allows analysts to delve deeper into the data, moving from high-level overviews to an in-depth investigation of Air in a Vehicle Brake System in Figure 2. The schematic structure of the proposed approach is to be divided into 3 phases: 1) Problem Description, 2) Weights, and 3) Ranking in Figure 3.

3. Literature review

In general, the brake system is the primary safety system for all vehicles. During overseas transportation with prolonged storage and high-temperature environment, Air can be generated in the brake system of the vehicles. When applying the TOPSIS [9] and EDAS technique similar to other MCDM (Multiple Criteria Decision Making) methods, accurate criteria weights must be assigned. This study outlines the general model based on three phases. Firstly, Fuzzy AHP [10] is utilized to obtain the subjective weights of the criteria through a questionnaire-based approach. Secondly, the TOPSIS technique is employed to assess and classify the alternatives using the obtained weights. Finally, EDAS technique is evaluate the alternatives ranking.

W. Khamwiangsa and S. Klongboonjit [7] introduced experiments to measure and validate the air volume in brake system with commercial vehicles for 4- caliper disc brakes specification. The experiment 3 methods showed the results from vehicles which are stored for a long period with high temperature and certain brake fluids combination for air generation.

W. Khamwiangsa and S. Klongboonjit [8] introduced Ward's method is extensively used for clustering problem concerning the potential of failure air in a vehicle brake system. The clusters resulting from ward methods were evaluated by the extent to which the various classifications were able to group brake air generate together.

M. Nazim, C. Mohammad and M. Sadiq [11] introduced developed to select the software requirements from the list of the elicited requirements using fuzzy analytic hierarchy process (AHP) and fuzzy technique for order of preference by similarity to ideal solution (TOPSIS) methods.

S.Abusaeed, S. Rehman and A. Mashkoor [12] introduced classifies and prioritizes the validated factors using a multi-criterion decision making Fuzzy-Analytic Hierarchy Process technique, which effectively rectifies the subjectivity and handles the uncertainty among the identified factors. The implementation results provide a list of prioritized cost overhead factors that would assist agile practitioners during the cost estimation process in the ASD context.

J. Sánchez-Lozano, J. Correa-Rubio and M. Fernández-Martínez [13] introduced combination of a modified version of Analytic Hierarchy Process (AHP; to determine the weights of the criteria) and Technique for Order of Preference by Similarity to ideal Solution (TOPSIS; to assess each set of alternatives) approaches with fuzzy logic.

H. Ali and J. Zhang [14] introduced combines economic and environmental factors with the foreign transportation risk criterion to develop a holistic model for global green supplier selection and order allocation (SS&OA) in the textile industry under all-unit quantity discounts. Initially, the fuzzy analytical hierarchy process (FAHP) method is used to calculate the relative weights of the criteria.

H. Arman [15] introduced developed for conventional fuzzy numbers (FNs), mainly triangular and trapezoidal FNs. The ascending and descending parts of triangular and trapezoidal membership functions (MFs) are straight lines.

J. Ren, Q. Zhang, Y. Zhang, K. Wei, K. Zhang, W. Ye and Y. Zhang [16] introduced entropy weight method-fuzzy analytic hierarchy process (EWM-FAHP), cracking interspace volume (CIV) and debonding interspace volume (DIV) and subsequent weights were proposed to measure the damage degree.

Z. Huang, C. Yang, X. Zhou and W. Gui [17] introduced evaluation problem from a new perspective, and an improved Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) based multi-criteria decision-making approach is proposed.

Y.Leng and H. Zhang [18] introduced evaluate data set of renewable energy development level is obtained. Next, a comprehensive evaluation method based on game theory combination weighting and TOPSIS is proposed.

S. Saini and S. Dubey [19] introduced recommendation of Diet to Jaundice Patient on the Basis of Nutrients Using AHP and Fuzzy AHP Technique.

S. Shaaban and A. El-latif [20] introduced Evaluation Based on Distance from Average Solution (EDAS) is proposed to rank available operating points for choosing the optimal combination of operating parameters of a diesel engine.

A. Torkayesh, M. Deveci, S. Karagoz and J. Antucheviciene [21] introduced and conducts a comprehensive literature review on developments, extensions, and applications of the EDAS method.

Previous research has indicated that there are issues with the brake system due to the presence of air and contamination. It would be beneficial to have an analytical approach to identify and rectify these problems, seeking simplified solutions and methods of analysis.

4. Methodology

In this study, the general outline of the model is based on three phases. Firstly, FAHP is utilized for weight calculation, obtaining subjective criteria weights through questionnaire results. Secondly, TOPSIS is employed for classifying calculation, serving as a practical and valuable technique for ranking and selecting a set of externally determined alternatives based on distance measures to reach the targets. Finally, EDAS is proposed to rank available operating points for choosing the optimal of critical factors and used to evaluate the alternatives ranking.

4.1 Data collection with questionnaire

In this study, the performance of the proposed method is evaluated based on collected data from the questionnaire [22]. A questionnaire is a tool used to gather information through a set of questions that require responses. The survey's primary objective is to collect data from 10 specialists, including automotive engineers and managers.

The FAHP model with objectives, criteria, and alternatives is divided into two parts: criteria and alternatives. The criteria are categorized into four levels: Level 1 criteria include three types of caliper brake coatings [23], Level 2 criteria pertain to maintenance costs, Level 3 criteria focus on transportation destinations across 7 continents, and Level 4 criteria address issues observed at speeds of 0 kph, 40 kph, 60 kph, 80 kph, and 100 kph [24].

These alternatives are evaluated by simulating the brake air in the vehicle system on proving ground observed at the speeds, respectively.

4.1.1 Determination of critical factors

In this paper four critical factors are selected which are highly recommended. The explanation of their criticality or why they are chosen as important factors is given below.

Criteria level 1 Caliper brake coatings (C_{A1}-C_{A3}): These are required to provide Caliper brake coatings type. The coating affects chemical reactions directly. The main cause of air in a vehicle brake system.

Criteria level 2 Maintenance costs (C_{B1}- C_{B2}): These are cost addition for manufacturers.

Criteria level 3 Transportation destinations (C_{c1}-C_{c7}): Thailand serves as a manufacturing base and produced vehicles for global export. The transport destinations and distances are important parameters of brake issue and air in a vehicle brake system generated.

Criteria level 4 Problem symptoms (C_{D1}- C_{D2}): the vehicle reached destination. it always leads to some issues in brake system such as the presence of air in a vehicle brake system and foreign contaminants. Table 1 below shows the criteria.

Table 1. Criteria for Evaluating Brake Issue

Criteria level 1 Caliper brake coatings	**Description**
C_{A1}	Non-coating
C_{A2}	Organic coating
C_{A3}	Inorganic coating
Criteria level 2 Maintenance costs	Description
C_{B1}	Labor costs
C_{B2}	Material costs
Criteria level 3 Transportation destinations	Description
C_{c1}	Africa
C_{c2}	Asia
C_{c3}	Europe
C_{c4}	North America
C_{c5}	South America
C_{c6}	Antarctica
C_{c7}	Australia
Criteria level 4 Problem symptoms	Description
C_{D1}	Air in the brake system
C_{D2}	Contamination

Table 2. Alternative to evaluate Air in a Vehicle Brake System

Alternative	**Description**
A_1	0 kph
A_2	40 kph
A_3	60 kph
A_4	80 kph
A_5	100 kph

Alternative (A_{1-} A_5): These are required to provide for evaluate air in a vehicle brake system on proving ground observed at speeds of 0 kph, 40 kph, 60 kph, 80 kph, and 100 kph. as described in Table 2.

Alternative (A_{1-} A_5): These are required to provide for evaluate air in a vehicle brake system on proving ground observed at speeds of 0 kph, 40 kph, 60 kph, 80 kph, and 100 kph. as described in Table 2.

4.2 Fuzzy analytic hierarchy process

Fuzzy Analytic Hierarchy Process, FAHP is an approach used to address multi-criteria decision-making, MCDM problems [25]. In MCDM, the decision maker evaluates and select the best alternatives based on predetermined criteria. To address the existing research gap, the researchers have developed a methodological framework, briefly outlined in this section. This framework employs a top-down approach, commencing with strategies and concluding with decisions. It consists of three steps or levels, each sharing a coherent structure, as illustrated in Figure 4. The structure encompasses a goal, a set of criteria, and a set of alternatives. While resembling the traditional FAHP layout, this framework remains versatile, allowing for the incorporation of various other multi-criteria decision-making tools, as described in Table 3 & 4.

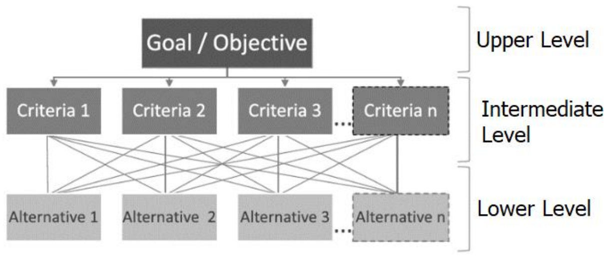

Figure. 4 Structure of each level of the framework [19]

Table 3. Fuzzified Pairwise Comparison Matrix

	Criteria 1	Criteria 2	Criteria 3	Criteria 4
Criteria 1	(1,1,1)	(4,5,6)	(3,4,5)	(6,7,8)
Criteria 2	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)
Criteria 3	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,2,3)	(1,1,1)	(2,3,4)
Criteria 4	$(\frac{1}{8},\frac{1}{7},\frac{1}{6})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)

Table 4. Fuzzified fundamental scale

Equal	1	(1,1,1)
Moderate	3	(2,3,4)
Strong	5	(4,5,6)
Very strong	7	(6,7,8)
Extremely strong	9	(9,9,9)
Intermediate values	2	(1,2,3)
	4	(3,4,5)
	6	(5,6,7)
	8	(7,8,9)

4.3 Technique for order performance by similarity to ideal solution process

In this section, the researchers explore a multi-attribute decision-making technique applicable to a group decision environment named TOPSIS [26]. TOPSIS is a practical and valuable technique used for ranking and selecting a set of externally determined alternatives through distance measures. The TOPSIS method can be elucidated through the following set of stages shown below:

Stage 1: Calculate normalized performance ratings.

In this procedure, each performance rating x_{ij} in X is divided by its norm. The normalized ratings y_{ij} (i = 1, 2,…, I; j = 1, 2,…, J) can be calculated by Eq. (1).

$$yij = xij\sqrt{\sum_{i=1}^{I} x^2 ij} \quad (1)$$

Stage 2: Integrate weigh with ratings as shown in Eq. (2).

$$vij = Wj * yij\,;\ (i = 1,2,\ldots,I;\ j = 1,2,\ldots,J) \quad (2)$$

Stage 3: Find positive and negative ideal solutions as shown in Eqs. (3) and (4).

$$A^* = \left[v^*{}_1, v^*{}_2, \ldots, v^*{}_j\right] \quad (3)$$

$$A^- = \left[v^-{}_1, v^-{}_2, \ldots, v^-{}_j\right] \quad (4)$$

Stage 4: Obtain the separation values as shown in Eqs. (5) and (6).

$$s^*{}_i = \sqrt{\sum_{j=1}^{j}\left(v_{ij} - v^*{}_j\right)^2} \quad (5)$$

$$s^-{}_i = \sqrt{\sum_{j=1}^{j}\left(v_{ij} - v^*{}_j\right)^2} \quad (6)$$

Stage 5: Calculate the overall preference score. The overall preference score V_i for each alternative A_i is obtained as shown in Eq. (7).

$$v_i = \frac{s^-{}_i}{s^-{}_i + s^*{}_i} \quad (7)$$

4.4 The evaluation based on distance from average solution

The evaluation based on the distance from average solution (EDAS) method [27] is a new distance-based measurement approach, contemporary to other recently developed MCDM methods. The mathematical modelling of EDAS method is based on the distances from the average solution rather than positive- and negative-ideal solutions.

Initial decision matrix. For a decision making problem with n criteria (n = 1, 2, …, j) and m alternative (m = 1, 2, … , i), initial decision matrix using Eq. (8).

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (8)$$

In normalization, average solution is determined considering all criteria. Average solution of each criterion j is calculated using Eq. (9).

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \quad (9)$$

Two important measures of the EDAS, PDA and NDA are calculated based on nature of conflicting criteria as follows. For a beneficial criterion, PDA and NDA values are derived using Eqs. (10, 11), and for cost criterion, PDA and NDA values are determined according using Eqs. (12, 13)

$$PDA_{ij} = \frac{\max(0, x_{ij} - AV_j)}{AV_j} \quad (10)$$

$$NDA_{ij} = \frac{\max(0, AV_j - x_{ij})}{AV_j} \quad (11)$$

$$PDA_{ij} = \frac{\max(0, AV_j - x_{ij})}{AV_j} \quad (12)$$

$$NDA_{ij} = \frac{\max(0, x_{ij} - AV_j)}{AV_j} \quad (13)$$

Weighted sum values of PDA and NDA are normalized using Eqs. (14) and (15).

$$NSP_i = \frac{SP_i}{max_i(SP_i)} \quad (14)$$

$$NSN_i = \frac{SN_i}{max_i(SN_i)} \quad (15)$$

compromise score of each alternative is determined using Eq. (16).

$$ASi = \frac{1}{2}(NSPi + NSNi) \quad (16)$$

5. Validation

5.1 Validation of the work by FAHP

FAHP (for weight calculation), is used to obtain the subjective weights of the criteria through the questionnaire results. The Fuzzified fundamental scale is utilized to categorize the key factors of the brake system for criteria at levels 1 to 4 and alternatives at level 5 in Figure 5.

We propose employing the FAHP to determine the weights of importance for the technical requirements in the decision-making process. The FAHP model, illustrated in Figure 6, focused on the brake system issues of the target vehicle. The model includes objectives, criteria, and alternatives. The alternatives are defined based on the performance specifications of the brake system. To facilitate the decision-making process, specialists engineering and design professionals possessing explicit knowledge in the domain are responsible for conducting pairwise comparisons of the elements.

Fuzzified fundamental scales are implemented to depict risk assessments in the risk priority ranking. The Fuzzified fundamental scale encompasses a range of values from Equal to Intermediate, as detailed in Table 5. The FAHP pairwise comparison matrix is utilized for the criteria level 1 for caliper brake coatings. The weights are calculated using the fuzzy geometric mean method as presented in Table 6.

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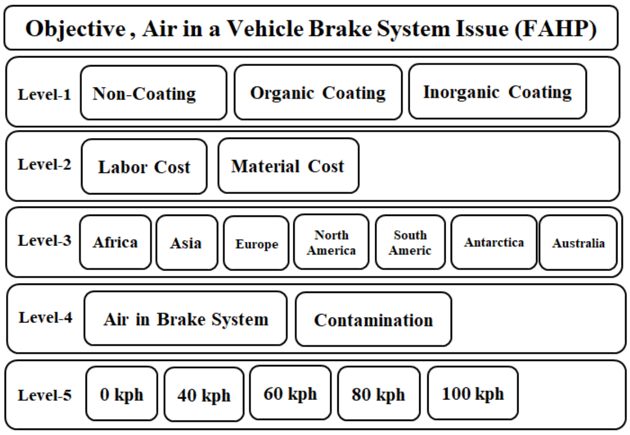

Figure. 5 Fuzzified Fundamental Scale

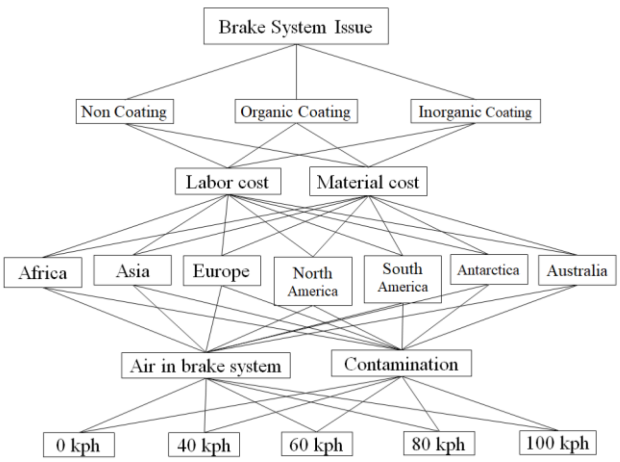

Figure. 6 Brake System Issues in the FAHP Model

Table 5. Fuzzified Fundamental Scale

Equal	1	(1,1,1)
Moderate	3	(2,3,4)
Strong	5	(4,5,6)
Very strong	7	(6,7,8)
Extremely strong	9	(9,9,9)
Intermediate values	2	(1,2,3)
	4	(3,4,5)
	6	(5,6,7)
	8	(7,8,9)

Table 6. Fuzzified Pairwise Comparison Matrix r_i for Criteria Level 1

	C_{A1}	C_{A2}	C_{A3}	Fuzzy value r_i
C_{A1}	(1,1,1)	$(\frac{1}{1},\frac{1}{2},\frac{1}{3})$	$(\frac{1}{1},\frac{1}{2},\frac{1}{3})$	(1.00,0.63,0.48)
C_{A2}	$(\frac{3}{1},\frac{2}{1},\frac{1}{1})$	(1,1,1)	$(\frac{1}{1},\frac{1}{2},\frac{1}{3})$	(1.44,1.00,0.69)
C_{A3}	$(\frac{3}{1},\frac{2}{1},\frac{1}{1})$	$(\frac{3}{1},\frac{2}{1},\frac{1}{1})$	(1,1,1)	(2.08,1.59,1.00)

Table 7. Summary of Centre of Area (COA) C_{A1}- C_{A3}

	Weight W_i	Normalized weight
C_{A1}	0.254	0.214
C_{A2}	0.376	0.317
C_{A3}	0.557	0.469

Table 8. Fuzzified Pairwise Comparison Matrix r_i for Criteria Level 3

	C_{c1}	C_{c2}	C_{c3}	C_{c4}	C_{c5}	C_{c6}	C_{c7}	Fuzzy value r_i
C_{c1}	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.00, 1.00, 1.00)
C_{c2}	(1,1,1)	(1,1,1)	(1,2,3)	(3,4,5)	(3,4,5)	(3,4,5)	(1,1,1)	(1.60, 2.00, 2.33)
C_{c3}	(1,1,1)	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(1,1,1)	(1.10, 1.06, 1.04)
C_{c4}	(1,1,1)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(1,1,1)	(3,4,5)	(1,1,1)	(0.91, 0.85, 0.82)
C_{c5}	(1,1,1)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(1,1,1)	(1,1,1)	(3,4,5)	(1,1,1)	(1.00, 1.00, 1.00)
C_{c6}	(1,1,1)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(1,1,1)	(0.62, 0.55, 0.50)
C_{c7}	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1.00, 1.00, 1.00)

Table 9. Summary of Centre of Area (COA) C_{c1}- C_{c7}

	Weight W_i	Normalized weight
C_{c1}	0.135	0.135
C_{c2}	0.246	0.246
C_{c3}	0.143	0.143
C_{c4}	0.115	0.115
C_{c5}	0.133	0.133
C_{c6}	0.075	0.075
C_{c7}	0.153	0.153

The result of a low value indicates high severity and high frequency, while a high value indicates low severity and low frequency. Specifically, C_{A1} (caliper brake with non-coating) exhibits high severity and high frequency, C_{A2} (caliper brake with organic coating) shows medium severity and medium frequency, and C_{A3} (caliper brake with inorganic coating) reflects low severity and low frequency, as detailed in Table 7.

The Fuzzified Pairwise comparison matrix is utilized for criteria level 3, transportation destinations. The weights are calculated using the fuzzy geometric mean method, as presented in Table 8.

Finally, the FAHP pairwise comparison matrix for criteria level 3, focusing on transportation primarily to 7 continents by sea freight, is constructed.

As for the result, a low value indicates high severity and high frequency, while a high value signifies low severity and low frequency. The criteria level 3 results for transportation primarily to 7 continents by sea freight are arranged in descending order as follows: Asia, Australia, Europe, Africa, South America, North America, and Antarctica, as presented in Table 9.

5.2 Validation of the work by TOPSIS

TOPSIS method evaluates and classifies the alternatives based on the obtained weights. The evaluation involves ranking the occurrence of significant problems and the frequency of problems in each criterion and alternative.

According to the relative closeness values, the worst alternative for the air brake in the brake system is C_{A1}, at caliper non-coating, and they are sorted out in ascending order, The low rank indicates high severity and high frequency, while the high rank signifies low severity and low frequency, as presented in Table 10.

According to the relative closeness values, the worst alternative for the air brake in the brake system primarily transported to 7 continents by sea freight is C_{c6} Antarctica. The alternatives are arranged in ascending order, with lower ranks signifying higher severity and frequency, while higher ranks denote lower severity and frequency. The order is as follows: Antarctica, North America, South America, Africa, Europe, Australia, and Asia, as outlined in Table 11.

Table 10. TOPSIS Scoring Table of Caliper coatings.

	A_1	A_2	A_3	A_4	A_5	P_i	Rank
C_{A1}	0.350	0.350	0.350	0.350	0.350	1.000	1
C_{A2}	0.220	0.220	0.220	0.220	0.220	0.733	2
C_{A3}	0.140	0.140	0.140	0.140	0.140	0.500	3
V_{i+}	0.350	0.350	0.350	0.350	0.350		
V_{i-}	0.140	0.140	0.140	0.140	0.140		

Table 11. TOPSIS Scoring Table of Destinations.

	C_{A1}	C_{A2}	C_{A3}	P_i	Rank
A_1	0.140	0.140	0.140	0.002	3
A_2	0.140	0.140	0.140	0.002	3
A_3	0.140	0.140	0.140	0.002	3
A_4	0.220	0.220	0.220	0.380	2
A_5	0.350	0.350	0.350	0.998	1
V_{i+}	0.049	0.049	0.049		
V_{i-}	0.020	0.020	0.020		

5.3 Validation of the work by EDAS

EDAS method evaluates and rank available operating points for choosing the optimal of critical factors and used to evaluate the alternatives ranking.

According to the relative closeness values, the worst alternative for the air brake in the brake system is C_{A1}, at caliper non-coating, and they are sorted out in ascending order, The low rank indicates high severity and high frequency, while the high rank signifies low severity and low frequency, as presented in Table 12.

Table 12. EDAS Scoring Table of Caliper coatings.

	SP_i	SN_i	NSP_i	NSN_i	AS_i	Rank
C_{A1}	0.146	0.043	1.000	0.176	0.588	1
C_{A2}	0.000	0.243	0.000	1.000	0.500	2
C_{A3}	0.050	0.086	0.343	0.353	0.348	3

Table 13. EDAS Scoring Table of Destinations.

	SP_i	SN_i	NSP_i	NSN_i	AS_i	Rank
C_{c1}	0.000	0.215	0.000	0.593	0.297	4
C_{c2}	0.000	0.048	0.000	0.132	0.066	7
C_{c3}	0.275	0.000	0.511	0.000	0.256	5
C_{c4}	0.000	0.363	0.000	1.000	0.500	2
C_{c5}	0.000	0.347	0.000	0.956	0.478	3
C_{c6}	0.538	0.215	1.000	0.593	0.796	1
C_{c7}	0.159	0.000	0.296	0.000	0.148	6

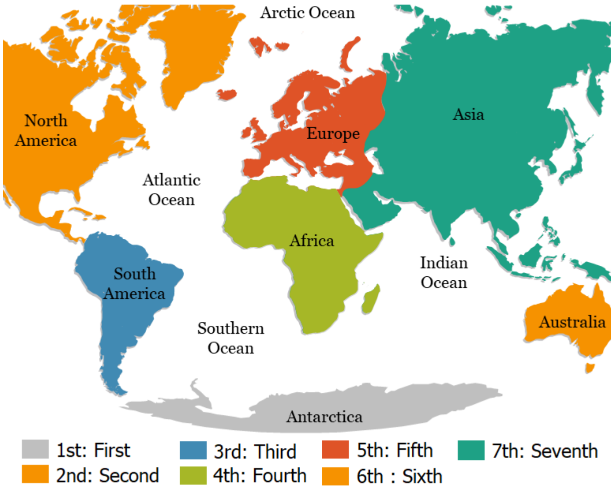

Figure. 7 The rankings for Transportation destinations [1]

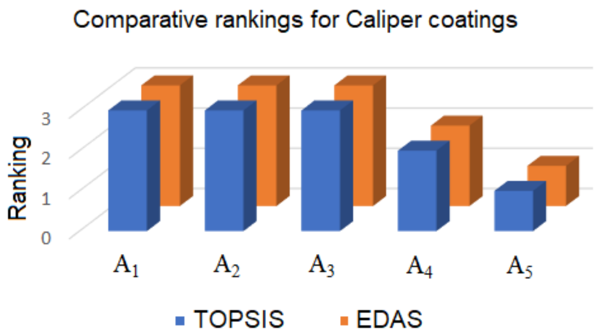

Figure. 8 Comparative rankings of the suggested method for Caliper coatings

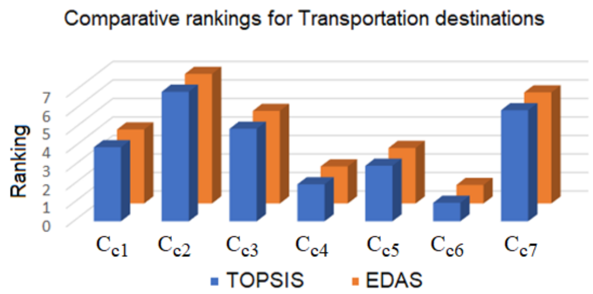

Figure. 9 Comparative rankings of the suggested method for Transportation destinations

According to the relative closeness values, the worst alternative for the air brake in the brake system primarily transported to 7 continents by sea freight is C_{c6} Antarctica. The alternatives are sorted out in ascending order, where the low rank indicates high severity and high frequency, while the high rank represents low severity and low frequency. The order is as follows: Antarctica, North America, South America, Africa, Europe, Australia, and Asia, as presented in Table 13. And Figure. 7.

A comparative analysis between the TOPSIS and EDAS methods. The Criteria level 1 Caliper brake coatings results correlate and the same direction in Figure. 8.

A comparative analysis between the TOPSIS and EDAS methods. The Criteria level 3 Transportation destinations results correlate and the same direction in Figure. 9.

6. Applications

According to the weight and rank results, we extracted Rejection per thousand analyses of vehicles with calipers brake with Non-coating, Organic coating, and Inorganic coating for transport destinations to verify for efficiency and effectiveness The results consist of 3 coating with 7 continents, which could be concluded and summarized as presented in Table 12.

The Rejection per thousand for Air in the Vehicle Brake System varies depending on the type of caliper coating. For calipers with non-coating, the rejection rate is 0.99 per thousand vehicles. For calipers with organic coating, the rejection rate is 0.12 per thousand vehicles, and for calipers with inorganic coating, the rejection rate is 0.03 per thousand vehicles. This implies that for every 1,000 vehicles, there is a risk of accidents if the air in the brake system is not repaired, with rejection rates as mentioned above.

The Rejection per thousand for Air in the Vehicle Brake System varies by transportation destination. For Antarctica, the rejection rate is 0.1, for North America it's 0.15, for South America it's 0.09, for Africa it's 0.05, for Europe it's 0.02, for Australia it's 0.01, and for Asia, it's 0. The results indicate that the Rejection per thousand for caliper brakes with inorganic coating (CA3) is significantly lower compared to other coatings across all transportation destinations.

Table 12. Rejection per thousand of Air in a Vehicle Brake System.

	C_{c1}	C_{c2}	C_{c3}	C_{c4}	C_{c5}	C_{c6}	C_{c7}
C_{A1}	0.04	0.00	0.02	0.10	0.07	0.12	0.01
C_{A2}	0.01	0.00	0.00	0.04	0.02	0.05	0.00
C_{A3}	0.00	0.00	0.00	0.01	0.00	0.02	0.00

Table 13. Brake air in system maintenance cost (US$) calculation for Rejection per thousand

	C_{c1}	C_{c2}	C_{c3}	C_{c4}	C_{c5}	C_{c6}	C_{c7}
C_{A1}	1,000	0	500	2,500	1,750	3,000	250
C_{A2}	250	0	0	1,000	500	1,250	0
C_{A3}	0	0	0	250	0	500	0

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From the number of Rejections per thousand that have been used to calculate the cost of both materials and labor, Material cost per vehicle is 10$ and Labor cost per vehicle is 25$ per vehicle as presented in Table 12.

The Brake air in system maintenance cost calculation is determined based on the Rejection per thousand for different brake caliper coatings: 9,000$ for non-coating, 3,000$ for organic coating, and 750$ for inorganic coating.

The Brake air in system maintenance cost calculation is determined based on the Rejection per thousand for different transportation destinations: 4,750$ for Antarctica, 3,750$ for North America, 2,250$ for South America, 1,250$ for Africa, 500$ for Europe, 250$ for Australia, and 0 for Asia. The results for C_{A3} (caliper brake with inorganic coating) provide significantly low maintenance costs.

The review of the top 3 rankings of Air in the Vehicle Brake System are Antarctica, North America, and South America, respectively. When comparing non-coating with inorganic coating, significant improvements are observed. In Antarctica, the Rejection per thousand decreases from 0.12% to 0.02%, and repair costs decrease from 3,000$ to 500$. In North America, the Rejection per thousand decreases from 0.10% to 0.01%, and repair costs decrease from 2,500$ to 250$. In South America, the Rejection per thousand decreases from 0.07% to 0%, and repair costs decrease from 1,750$ to 0$. These bring the defect rate of Air in the Vehicle Brake System significantly closer to the targets of 0% and 0 defects.

7. Results and discussion

The FAHP validation results for C_{A1} (caliper brake with non-coating) indicate high severity and high frequency. The results for C_{A2} (caliper brake with organic coating) suggest medium severity and medium frequency Lastly, the results for C_{A3} (caliper brake with inorganic coating) signify low severity and low frequency. Regarding transportation to 7 continents by sea freight, the result is ranked as follows: Antarctica, North America, South America, Africa, Europe, Australia, and Asia respectively.

The TOPSIS validation results indicate that the worst alternative for the air brake in the brake system is C_{A1} (caliper brake with non-coating) and A_5, at 100 kph, with low severity and high frequency ranking the lowest and low severity and low frequency ranking the highest. Similarly, the most unfavorable alternative for the air brake in the brake system transported primarily to 7 continents by sea freight is C_{c6} Antarctica, with low severity and high frequency ranking the lowest, and low severity and low frequency ranking the highest.

The EDAS validation for The Criteria level 1 Caliper brake coatings and The Criteria level 3 Transportation destinations results correlate and the same direction as TOPSIS.

In the validation result report, it is observed that CA3 (caliper brake with inorganic coating) exhibits significantly lower Rejection per thousand and maintenance costs, aligning with the assumptions made in FAHP, TOPSIS, and EDAS results. In the experimental result report, the defect rate of Air in the Vehicle Brake System is markedly decreased, approaching 0 defects and repair costs. Table 12 reveals that the remaining 0.03% defect rate for C_{A3} is attributed to external factors, including various root causes such as part quality and assembly process issues, which fall outside the scope of this study.

8. Conclusion

In this study, we propose evaluating and validating the brake system issues involving the presence of air bubbles and contaminants in the brake system of commercial vehicles equipped with all-wheel caliper brakes. The evaluation comprises two methods: FAHP for weight calculation. TOPSIS and EDAS for ranking, based on data collected from a questionnaire administered to 10 specialists, considering 4 criteria levels and alternatives. TOPSIS and EDAS ranking compare results are correlated and in the same direction.

The proposed technique has proven highly effective in reducing the occurrence of Air in the Vehicle Brake System. In Antarctica, the defect rate decreased by 0.1%, resulting in a reduction of repair costs by 2,500$. Similarly, in North America, the defect rate decreased by 0.09%, leading to a reduction in repair costs by 2,250$. Additionally, in South America, the defect rate decreased by 0.07%, resulting in a reduction of repair costs by 1,750$. Overall, these results demonstrate a significant reduction in the defect rate of Air in the Vehicle Brake System and a notable decrease in repair costs.

As a result, the caliper brake coated with inorganic material are recommended for commercial vehicles intended for exportation, as they exhibit no issues in the brake system, eliminate the formation of air bubbles and contaminants, and prevent repair costs, labour expenses, and material wastes. Additionally, performance testing of the brake system in vehicles demonstrates its capability to reduce speed, control braking, and facilitate

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stopping under the driver's control, ultimately reducing road accident rates.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Weerachai Khamwiangsa was the primary author who conceptualized, implemented the concept, collected results and documented the paper. Sakon Klongboonjit reviewed the work, suggested changes and verified the results.

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