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An application of Confirmatory Factor Analysis (CFA) for measurement modeling on rail freight performance indicators: Case study on Thailand's new double-track railway

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Abstract

The main objective of this research is to formulate a measurement model encompassing rail freight performance indicators for newly established double-track railway routes through the application of Confirmatory Factor Analysis (CFA). Employing a questionnaire as the primary data collection tool, this study specifically focuses on factors related to rail freight performance. The sample size comprises 150 entrepreneurs, including Logistics Service Providers (LSPs), warehouse operators, and distribution center operators. The performance indicators utilized in this investigation, derived from an extensive literature review, constitute the relevant factors. Subsequently, the performance indicators of rail freight transportation were analyzed using Confirmatory Factor Analysis (CFA). The findings indicate a consistent alignment between the proposed model and empirical data ($\chi 2$ = 244.728, $\chi 2$ /df = .967, df = 253, p = .634, GFI = .990, AGFI = .970, CFI = 1.000, RMR = .036, RMSEA = .000). Based on the result of the proposed measurement model, the most significant performance indicator is Cost (transportation costs), exerting considerable influence on entrepreneurs in their selection of transportation modes. Other indicators, namely, Time (transportation time), Reliability, Network (rail network accessibility), Security, Facility and Equipment, are deemed secondary factors. Consequently, organizations responsible for the operation of double-track railways must prioritize attention to these indicators to incentivize entrepreneurs to opt for rail transportation, thereby augmenting the volume of the rail transport mode.

Keywords: Performance indicator, Rail freight transportation mode, Confirmatory Factor Analysis (CFA), Factor Analysis

1. Introduction

Freight transportation encompasses the movement of goods between different locations, thereby generating both place utility and time utility. Transportation activity adds value to goods by enhancing their accessibility and reducing transit time. The uninterrupted provision of services serves as a key indicator of time utility [1, 2]. The significance of transportation infrastructure development extends from its ability to enhance national competitiveness. Therefore, the Thai government has prioritized the development of transportation infrastructure.

There are many plans for transportation infrastructure development, that is road transportation infrastructure development, rail transportation infrastructure development, maritime transportation infrastructure development, and air transportation infrastructure development. In the development plan for rail transportation infrastructure, there are 2 parts i.e., high-speed trains will be developed for passenger transportation, and double track train program is developed for both passengers and freight, but the majority of the benefits will be contributed from freight transportation. These 2 types of rail modes will be promoted as the backbone of the transportation system in Thailand, in which the feeder transportation mode is served in a manner similar to the road transportation mode. In this study, freight transportation is considered due to the direction of the development plan for freight transportation, and it is considered for increasing the portion of the rail mode. The goal of this development plan is to increase overall transportation volume of rail mode by 30% [3]. The route network of double-track railway will facilitate seamless travel and efficient freight transport along each region of Thailand, thereby establishing a comprehensive transportation network [4]. Moreover, this railway network assumes a crucial role as a pivotal gateway for Thailand's border trade, providing ample opportunities to distribute goods to other countries.

The aim of the development plan for double-track trains in Thailand is to increase the volume of rail freight transportation due to the high logistics cost of Thailand currently. The modal shift of freight transportation from road mode to rail mode might help to reduce the logistics cost. However, the development of infrastructure for double-track trains cannot confirm that freight transportation will be shifted to rail mode. There are many factors for entrepreneurs that are used for selecting the mode to earn as much as benefits. The factors affecting the decision to select the rail mode can be defined as indicators for rail freight transportation. Mlinarić et al. [5] developed a framework for investigating a comprehensive set of Key Performance Indicators (KPIs) for the assessment of railway intelligence. The cost, technical, technology, mobility, safety, reliability, pollution reduction, and energy efficiency were defined as the indicators in terms of railway intelligence [5]. Jung et al. [6] analyzed factors for selecting an international freight transportation mode, which consists of transportation cost, availability of transportation service, reliability of transportation service, and convenience

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of transportation service. Arencibia et al. [7] analyzed demand for freight transport in the context of modal choice. The indicators that used to analyze the demand for freight transport consist of transportation cost, transit time, punctuality, and service frequency. Tavasszy et al. [8] investigated the importance of freight mode choice criteria. The requirements for transportation modes are abstracted into a set of criteria, including transportation cost, door-to-door travel time, on-time reliability, flexibility, frequency, and reduction of CO_2 emissions [8].

Therefore, this research is focused on developing a model to measure the performance indicators of rail transportation by applying Confirmatory Factor Analysis (CFA). The CFA is a statistical method that "seeks to confirm if the number of factors (or constructs) and the loadings of observed (indicator) variables on them conform to what is expected on the basis of theory" [9]. Based on this approach, this study aims to establish a comprehensive performance measurement framework for the existing shipping systems and in the case of the development of the new double-track railway infrastructure.

2. Materials and methods

2.1 Research methodology

This research aims to develop the measurement modeling on rail freight performance indicators by applying Confirmatory Factor Analysis (CFA). The methodology of this study consists of 1) defining the research problem, 2) literature review, 3) designing and validating method, 4) collecting data, 5) developing measurement model and 6) conclusion. Figure 1 shows the details of each step.

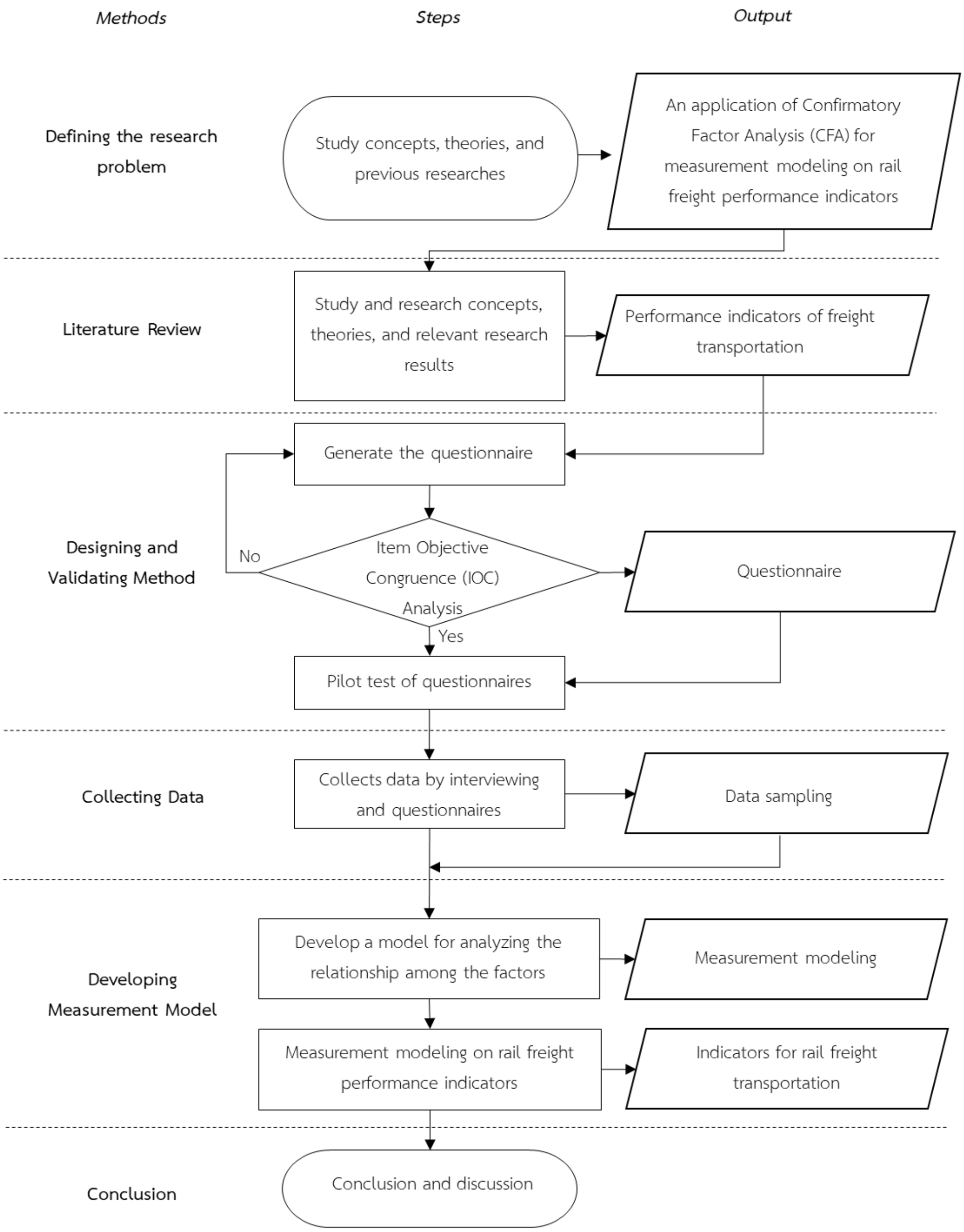

Figure 1 Research methodology

2.2 Population and sample

This study discusses the analysis of performance indicators for rail freight transportation efficiency in the case of Thailand's new dual-track railway system. The research population for this study includes Logistics Service Providers (LSPs), warehouse operators, and distribution center operators who are involved in freight transportation. The selection criteria for obtaining a suitable sample group for data processing involve certain characteristics and conditions related to businesses engaged in freight transportation and distribution. These businesses encompass warehouse operators, logistics and transportation operators, and distribution center operators. Small-scale businesses with limited customer bases or specialized local services, such as short-distance transportation within regions or express deliveries in communities, are excluded.

The research population consists of 221 companies [10]. The sample group meeting the criteria for this study comprises a total of 142 companies, excluding small-scale businesses, based on the population calculation method by Taro Yamané at the 0.05 significant level. The detailed breakdown of the sample group includes:

- Freight transportation service providers with container packaging: 64 companies;
- Cold storage or frozen goods transportation service providers: 20 companies;
- Other freight transportation service providers: 2,746 companies (excluding 95% of small-scale businesses), after excluding small-scale businesses, the remaining businesses eligible for the research amount to 137 companies.

To assess the appropriateness of the sample group used in this research, the researcher considered the size of the sample group that is suitable for data analysis using the AMOS program. The analysis was conducted employing the Structural Equation Model (SEM) technique, as recommended by Hair et al. [11]. The sample size for this study was determined based on established guidelines for model analysis. Hair et al. [11, 12] proposed a criterion to determine the minimum sample size required by considering the research's characteristics. Therefore, there are 6 latent variables, and each latent variable must have 7 observed variables, communalities should be 0.5 or greater [12]. Based on these criteria, a minimum sample size should be 150 samples approximately. Then the sample size of 150 was defined to ensure adherence to the specified requirements and to facilitate accurate statistical calculations. In addition, the purposive sampling was used as a sampling method in data collection stage.

Based on the research objective, this study designed a structured questionnaire and conducted surveys with entrepreneurs. The respondents were asked to answer questions based on their current freight transportation, firm characteristics, and their freight transportation experiences. The basic information of samples is shown in Table 1. The research samples were reasonable and represented the main groups engaged in freight transportation.

Table 1 Sample Basic Information

Item	Number	Percentage
Position of Respondent in the Company		
- Owner	67	45
- Manager	62	41
- Head of transportation department	21	14
Type of product (produce/transport)		
- Household products	29	19
- Charcoal and electrical generating equipment	2	1
- Industrial products	27	18
- Pharmaceutical and cosmetic products	21	14
- Electrical equipment and appliances	20	13
- Construction materials	12	8
- Vegetables and fruits	39	26
Channel of Distribution		
- Domestic	90	60
- International	60	40
Average production capacity/average transportation volume		
- < 1,000 tons/year	45	30
- 1,000 – 5000 tons/year	15	10
- 5,001 – 10,000 tons/year	15	10
- > 10,000 tons/year	75	50
Freight transportation mode		
- Road mode	105	70
- Maritime mode	45	30
- Rail mode	-	-
- Air mode	-	-

2.3 Validity and reliability

The questionnaire was used to collect data from the sample mentioned in the population and sample section. The quality of the questionnaire was validated by calculating the Index Objective Congruence (IOC). The IOC was conducted by taking the score from three experts to ensure content validity of each question item in questionnaire. The criteria of the IOC were defined using the average score, and where question items in the questionnaire have an average score greater than or equal to 0.50, the question is acceptable. Subsequently, the questions were revised based on expert recommendations, leading to the development of a well-crafted questionnaire. The IOC analysis shows that the average score is 0.67 - 1.00 in this study. Then the questionnaire was tested with 30 samples to assess its reliability. The reliability test was conducted by using Cronbach's Alpha Coefficient, which yielded a value of 0.79. This coefficient exceeded the acceptable threshold of 0.50 for affirming the questionnaire's reliability [13]. In this study, model consistancy has been checked all criteria based on the value in Table 2.

Table 2 Statistical Values and Criteria for Model Consistency

Statistical Values	Criteria for Model Consistency
Chi-Square (χ^2)	$0.05 < p \leq 1.00$
Relative Chi-Square (χ^2/df)	$0 < \chi^2/df \leq 2.00$
The Goodness of Fit Index (GFI)	$0.95 \leq GFI \leq 1.00$
The Adjusted Goodness of Fit Index (AGFI)	$0.95 \leq AGFI \leq 1.00$
The Comparative Fit Index (CFI)	$0.90 \leq CFI \leq 1.00$
Root Mean Square Error of Approximation (RMSEA)	$0.00 \leq RMSEA \leq 0.05$
Root of Mean Square Residual (RMR)	$0.0 \leq RMR \leq 0.05$

Source: Schumacker and Lomax [14]

2.4 Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) is a statistical method. The CFA is employed to validate measurement models by testing relationships among latent variables and observed variables [11, 15]. Its purpose is to unveil the underlying structure of relationships between variables and identify the latent factors that influence the observed variables [16]. The CFA must utilize specialized software to analyze the aspects of measurement models, assessing the relation among latent variables and their respective indicators, and exploring the interrelationships among the indicators themselves. After conducting a thorough analysis using CFA, we have evaluated the adequacy of the proposed measurement model and its overall fit with the data.

CFA is indeed a statistical technique used to confirm the factor structure of a set of observed variables and their relationships to latent variables or constructs. In the context of rail freight transportation, the indicators or observed variables could include various factors that directly or indirectly impact the efficiency and performance of the system. These factors may be drawn from experts who are related to rail freight field, existing literature, industry knowledge, or government reports related to rail freight. Some potential indicators for rail freight transportation efficiency are shown in Table 3 [17-19].

Table 3 Related indicators for rail freight

Indicator	Haron et al. [17]	Tripathi et al. [18]	Vedant [19]	Expert review
Cost (transportation costs)		✓	✓	✓
Security / safety	✓		✓	✓
Reliability / performance	✓	✓	✓	✓
Time (transportation time)		✓	✓	✓
Network (rail network accessibility)	✓			✓
Physical Facilities / Facility and equipment	✓			✓
Characteristics of goods			✓	
Environmental Impact / Sustainability	✓	✓		
Visibility		✓		

3. Results

Based on reviewing freight transportation performance indicators, 6 key factors were defined as crucial elements in selecting the transportation mode for entrepreneurs. These 6 key factors have been defined as rail freight performance indicators, which consist of Cost (transportation costs), Time (transportation time), Reliability, Network (rail network accessibility), Security, Facility and Equipment. These rail freight performance indicators were utilized as the question items in the questionnaire, which was used to collect data for 150 samples of entrepreneurs, i.e., Logistics Service Providers (LSPs), warehouse operators, and distribution center operators. The results obtained from the questionnaire revealed that the Cost (transportation costs) indicator was regarded as the most crucial by the entrepreneurs. Table 4 presents Mean and Standard Deviation of rail freight performance indicators.

Table 4 Mean and Standard Deviation of rail freight performance indicators

Rail freight performance indicators	$\overline{X}$	S.D.	Significance Level
1. Cost (transportation costs)	4.39	0.29	High
2. Security	4.24	0.37	High
3. Reliability	4.20	0.35	High
4. Time (transportation time)	4.15	0.39	High
5. Network (rail network accessibility)	3.92	0.38	High
6. Facility and equipment	3.73	0.45	High
Overall	**4.10**	**0.37**	**High**

From Table 4, all of the indicators have a high significance level, with an overall average value of 4.10 and a standard deviation of 0.37. Based on the value of mean and standard deviation, it is apparent that all indicators are considered significance as high level i.e., Cost (transportation costs) being the primary indicator ($\overline{X}$ = 4.39, S.D. = 0.29). In addition, security ($\overline{X}$ = 4.24, S.D. = 0.37), reliability ($\overline{X}$ = 4.20, S.D. = 0.35), transportation time ($\overline{X}$ = 4.15, S.D. = 0.39), rail network accessibility ($\overline{X}$ = 3.92, S.D. = 0.38), and facilities for supporting rail mode ($\overline{X}$ = 3.73, S.D. = 0.45) are considered minor indicators.

The overall reliability of latent variables through Composite Reliability (CR) and the analysis of the Average Variance Extracted (AVE), representing the average variance of latent variables that explains the observed variables. The CR should ideally have a value greater than 0.60. The analysis results reveal that the maximum value is 0.769, and the minimum value is 0.618, both exceeding the recommended threshold of 0.600. Additionally, the AVE should ideally be greater than 0.50. The analysis indicates that the maximum AVE value is 0.544, and the minimum is 0.501, surpassing the recommended threshold of 0.50 as shown in Table 5. These values suggest that each latent variable can effectively explain the variance of the observed variables, and the model evaluation provides clear evidence that the definition of all latent variables is accurate and reliable [20].

The first-order and second-order confirmatory factors have been analyzed to conduct the measurement model on rail freight performance indicators. The first-order confirmatory factor consists of 6 latent variables, that is Cost (transportation costs), Time (transportation time), Reliability, Network (rail network accessibility), Security, Facility and Equipment. Additionally, the second-order confirmatory factor has been included to represent the rail freight performance indicators as a single latent variable. This analysis aimed to assess the appropriateness and validity of the measurement model by considering the component weights and the reliability coefficient (R^2) of the variables, which were examined the covariance of the observed variables. The findings of the analysis are shown in Table 5.

Table 5 The results of the first-order and second-order confirmatory component analysis

Latent variable	Observable variable	Component weight value				CR	AVE
		Weight	S.E.	T	R^2		
Cost (transportation costs)	AA1	0.80	***	***	0.30		
	AA2	0.38	0.43	8.80	0.59		
	AA3	0.35	0.36	9.70	0.40		
	AA4	0.86	22.20	0.40	0.16		
	AA5	0.70	0.31	2.24	0.33		
Time (transportation time)	BB1	0.41	***	***	0.67		
	BB2	0.73	0.86	8.50	0.67		
	BB3	0.90	1.90	4.70	0.40		
	BB4	0.60	1.32	4.50	0.57		
Reliability	CC1	0.58	***	***	0.53		
	CC2	0.49	0.58	8.40	0.51		
	CC3	0.24	0.31	7.80	0.48		
	CC4	0.27	0.33	8.20	0.50		
Network (rail network accessibility)	DD1	0.62	***	***	0.60		
	DD2	0.33	0.63	5.20	0.63		
	DD3	0.53	4.06	1.30	0.43		
	DD4	0.93	0.84	11.10	0.58		
Security	EE1	0.73	***	***	0.67		
	EE2	0.39	6.94	0.60	0.15		
	EE3	0.43	0.47	9.10	0.35		
	EE4	0.32	0.59	5.40	0.68		
Facility and equipment	FF1	0.64	***	***	0.79		
	FF2	0.33	0.71	4.60	0.81		
	FF3	0.91	0.07	13.00	0.31		
Railway Performance Indicator	Cost	0.72	0.15	4.80*	0.00	0.769	0.544
	Time	0.56	0.05	12.17*	-0.10	0.637	0.508
	Reliability	0.60	0.27	2.24*	0.08	0.640	0.530
	Network	0.45	0.06	7.76*	-0.03	0.623	0.507
	Security	0.67	0.08	7.98*	0.05	0.715	0.536
	Facility and equipment	0.36	0.06	6.1*	0.08	0.618	0.501

Note: *t-value ≥± 1.96 has significance at .05 level, **t-value ≥± 2.58 has significance at .01 level,
R^2 = coefficient of reliability of the variable, *** Mandatory parameters therefore do not report S.E. and T values.

Based on Table 5, it shows that all variables exhibited positive component weights that are statistically significant at a level of 0.05. The transportation cost indicator has the highest component weight of 0.72, which means a strong influence on the overall measurement model. The security indicator has a component weight of 0.67, which means a substantial contribution. Additionally, the reliability indicator has a component weight of 0.60, while transportation time and rail network accessibility have component weights of 0.56 and 0.45, respectively. On the other hand, the indicator for service, tools, and equipment for handling goods has the lowest component weight of 0.36. These component weights provide insights into the relative importance of each indicator within the measurement model, emphasizing the significant role of transportation cost and security in the context of rail freight performance indicators.

Then the measurement model on newly rail freight performance indicators has been analyzed by using the Maximum Likelihood Method (MLE). This analysis aimed to estimate the parameters of an assumed probability distribution, given some observed data by considering various criteria for evaluating the fit of model. The evaluation criteria consist of Chi-squared test (X^2), CHI-SQUARE/DF, Degrees of Freedom (DF), p-value (P), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Comparative Fit Index (CFI), Root Mean Square Residual (RMR), and Root Mean Square Error of Approximation (RMSEA) index values, which are shown in Table 6 and Figure 2.

Table 6 Model consistency index with empirical data

Consistency index	Consistency evaluation criteria	Statistics	Result
χ^2	$0.05 < p \leq 1.00$	0.634	pass the criteria
χ^2/df	$0 < \chi^2/df \leq 2.00$	0.967	pass the criteria
GFI	$0.95 \leq GFI \leq 1.00$	0.990	pass the criteria
AGFI	$0.95 \leq GFI \leq 1.00$	0.970	pass the criteria
CFI	$0.90 \leq CFI \leq 1.00$	1.000	pass the criteria
RMSEA	$0.00 \leq RMSEA \leq 0.05$	0.000	pass the criteria
RMR	$0.00 \leq RMR \leq 0.05$	0.036	pass the criteria

From Table 6, the model has a high level of consistency between the measurement model and the empirical data. The evaluation of conformity revealed that 7 conformity indexes successfully passed the evaluation criteria. The specific index values are as follows: CHI-SQUARE = 244.728, CHI-SQUARE/DF = 0.967, DF = 253, P = 0.634, GFI = 0.990, AGFI = 0.970, CFI = 1.000, RMR = 0.036, and RMSEA = 0.000. These results provide strong evidence to conclude that the measurement model is fit and exhibits a high level of consistency with the empirical data.

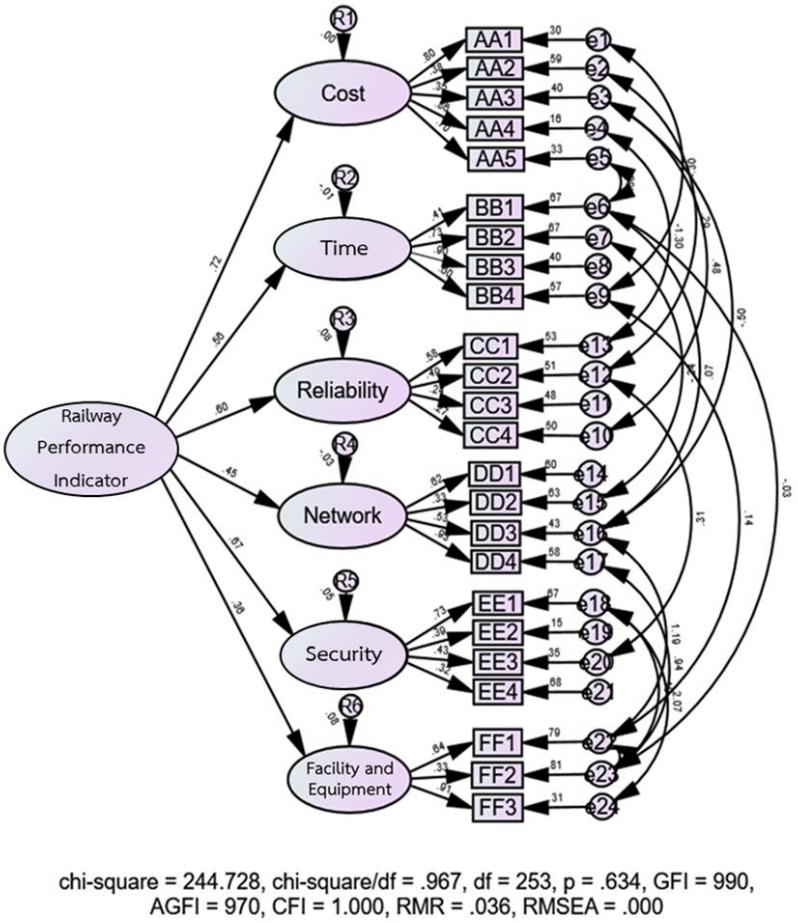

Figure 2 Results of the model analysis for the measurement modeling on rail freight performance indicators

4. Discussion

This paper focuses on analyzing the performance indicators relevant to the rail freight transportation of entrepreneurs, which consists of LSPs, warehouse operators, and distribution center operators. Based on the literature review of the previous study, all relevant performance indicators that influence the performance of rail freight transportation can be extracted. The indicators are Cost (transportation costs), Time (transportation time), Reliability, Network (rail network accessibility), Security, Facility and Equipment. In terms of the overall importance level, all performance indicators are considered as high significance, i.e. 1) Cost (transportation costs) ($\bar{X}$ = 4.39, S.D. = 0.29), 2) Security ($\bar{X}$ = 4.24, S.D. = 0.37), 3) Reliability ($\bar{X}$ = 4.20, S.D. = 0.35), 4) Time (transportation time) ($\bar{X}$ = 4.15, S.D. = 0.39), 5) Network (rail network accessibility) ($\bar{X}$ = 3.92, S.D. = 0.38) and 6) Facility and Equipment ($\bar{X}$ = 3.73, S.D. = 0.45) respectively. These results agree with the research of Jung et al. [6] who studied "importance analysis of decision-making factors for selecting international freight transportation mode". The results of this research found that transportation costs are important to selecting transportation modes at a high significance level. Additionally, the research of Tavasszy et al. [8] studied "Importance of freight mode choice criteria: An MCDA approach". It was found that transportation cost is viewed as the most important, closely followed by on-time reliability, while reduction of CO_2 emission is viewed as the least important.

The proposed measurement model on rail freight performance indicator has found that the measurement model is consistent with the empirical data, with the values of CHI-SQUARE =244.728, CHI-SQUARE/DF = .967, DF = 253, P = .634, GFI = .990, AGFI = .970, CFI = 1.000, RMR = .036 and RMSEA = .000. The variables show a positive and statistically significant correlation at the 0.05 level. The order of indicators for the performance of rail freight transportation of entrepreneurs are 1) Cost (transportation costs), 2) Security, 3) Reliability, 4) Time (transportation time), 5) Network (rail network accessibility) and 6) Facility and Equipment, which agrees with Arencibia et. al. [7] a study was conducted on modelling mode choice for freight transport using advanced choice experiments. The results indicated that transportation costs, transit time, service frequency, and delay significantly influence the choice of transportation modes. Moreover, Kim et al. [21] studied freight transport mode choice and mode shift in New Zealand. Their research revealed that the factors influencing the choice of transportation modes were timeliness, cost, accessibility, damage and loss, customer service, and suitability vary between industry groups and business types.

Confirmatory Factor Analysis (CFA) is a powerful statistical technique used to test the validity of a hypothesized factor structure within a set of observed variables. In this analysis, we obtained an excellent fit to the data, indicated by the Comparative Fit Index (CFI) value of 1.000 and the Root Mean Square Error of Approximation (RMSEA) value of .000. These results suggest that the proposed model fits the data exceptionally well, with the observed variables adequately capturing the underlying constructs.

While the obtained CFA results are indicative of a well-fitting model, it's important to consider the potential impact of the sample size on these findings. In some cases, extremely high fit indices such as CFI = 1.000 and RMSEA = .000 may raise concerns about overfitting, especially in smaller samples.

In the context of small sample sizes, there is an increased risk of obtaining inflated fit indices due to chance or sampling variability. Small samples may not adequately represent the population, leading to spurious findings that do not generalize beyond the current sample. Given the potential influence of sample size on CFA results, it is essential to interpret the findings cautiously. Replication of the analysis with a larger, more diverse sample would provide greater confidence in the stability and generalizability of the model. Additionally, conducting sensitivity analyses or exploring alternative model specifications can help assess the robustness of the results across different samples.

In conclusion, while the CFA results with CFI = 1.000 and RMSEA = .000 suggest an excellent fit to the data, the interpretation should be tempered by the consideration of the small sample size. Future research should aim to replicate these findings in larger samples to ensure the reliability and validity of the proposed factor structure.

5. Conclusions

This research aims to apply the Confirmatory Factor Analysis (CFA) for developing the measurement modeling on rail freight transportation performance indicators, which concentrate on the government's plan for a new double-track railway. The results of the research show that the measurement model is consistent with the empirical data, with the values of CHI-SQUARE =244.728, CHI-SQUARE/DF = .967, DF = 253, P = .634, GFI = .990, AGFI = .970, CFI = 1.000, RMR = .036 and RMSEA = .000. The variables show a positive and statistically significant correlation at the 0.05 level. The significant indicators for rail freight transportation are 1) Cost (transportation costs), 2) Security, 3) Reliability, 4) Time (transportation time), 5) Network (rail network accessibility) and 6) Facility and Equipment, respectively.

Furthermore, the results of the hypothesis testing for all 6 performance indicators demonstrated their significant influence on the performance of the rail freight transportation system. These findings underline the necessity for a substantial shift from road transportation to alternative modes of transport. This aligns with the strategic direction outlined by the Ministry of Transport, which designates rail transport as the primary means of transporting products and facilitating people's travel. Consequently, the relevant agencies should prioritize these indicators to encourage entrepreneurs to transition their transportation modes and utilize rail transport in a greater portion. These significant indicators for rail freight transportation can be the initiation of policies of an operator to engage the industry stakeholders to shift the transportation mode.

6. Acknowledgements

The research presented in this paper builds upon the findings of master thesis titled "Measurement model of rail freight performance indicators: Case study Mae Sot-Tak-Kamphaeng Pet-Nakon Sawan Double Track Railway", which was completed at Naresuan University in 2022. Specifically, the experimental framework and initial data analysis described in Chapters 3 and 4 of the thesis served as the foundation for the current study. While some aspects of the methodology and results overlap with the thesis, this manuscript presents novel insights and expanded analyses not previously included.

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