COMPARISON OF RURAL ROAD PRIORITISATION BETWEEN STRUCTURAL EQUATION MODELLING (SEM) PROCESS AND ANALYTIC HIERARCHY PROCESS (AHP) TO APPROACH THE SUITABLE AND EFFECTIVE ANALYSIS

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ABSTRACT

The main form of transport in Thailand logistics is road transport followed by port, rail and air transport respectively. Because of the road structure the most advance so all the road network is connected hence it provides the most convenient than other means of transport. However, the road transport is costly due to higher fuel and labour cost. Therefore, the Thai government has a policy to support multimodal transport as it is a key mechanism in the development of logistics. This research found that the most value of exports and a potential of multimodal transport product is rice, this product is one of the three export products of Thailand. The rice plantations are located in the lower northern and upper central region of Thailand and distributed centre is in Nakhon Sawan which is the major source of market crops. The main transports are by car or rail to the port in Ayutthaya and then transfer to ship to Bangkok Port; Laemchabang Port and Ko Srichang Port, or to Inland Container Depot in Lad Krabang to forward by rails to port for export. However, its ability to connect rice transports have limitations particularly transport of rice from farm to a collection centre. There are many rural roads involved these transports and those rural roads may not have been designed to support the weight of the cargo which resulted in damaging the roads. Therefore, the Department of Rural Roads has started to improve the efficiency of rural road connectivity to rail and port also managing proper road maintenance to ensure the safety for road users.

This research applied two methods to collect data and compare these methods to find which one is suitable for the department. First method is Analytic Hierarchy Process (AHP) is to prepare a questionnaire and collect in the area of studies, the information was evaluated on the factors that influence the selection of the roads. Department of Rural Roads then would develop a network of improve the transportation connectivity. The second method is to collect data and analyse using Structural Equation Modelling, SEM, for a summary of factors that influence the selection roads. These two methods were determined the relationship between them with different factors and concluded with the guidelines for a proper analyse and performance. However, in order to analyse the selected roads of the two methods have both advantages and limitations. Such as, the AHP method has the main factors which can be divided into various sub-factors and can be analysed in more detail, however, the analysis in this way based on the assumption that the individual factors are not related to the data used. Moreover, the analysis of expert interviews from which to recruit into those capable of providing information can be very complicated and May affect Understanding of the interviewees. SEM method has relationship of each factor by factor, the assumption that change of one factor has an impact of changes in other factors both directly and indirectly which can reflect a real operational, however this analysis can be

complicated and require large amounts of data for accurate analysis. This study can be concluded that the project that has many factors closely related to several other factors should be used SEM method analysis which can reflect the real performance. For the AHP analysis is suitable for the project that can be divided into the sub-factors out of several sequences which will be able to determine the importance of each factor and sub-factor throughout.

1. INTRODUCTION

Currently, logistic system of agricultural products in Thailand has low efficiency (Termpittayasit, 2011), especially on rice. Logistics of rice include several parts, such as agriculturists, distribution centers, and exporters. In Thailand, rice is generally transported by trucks. Development of road network will help reduce the time period of transportation (Theppitak, 2013). Moreover, the multimodal connection to train station and port will lead to the multimodal transportation that causes the increasing of efficiency and decreasing of the transportation cost (Polyeam, 2013). In addition, the physical characteristics of rice is highly insensitive to heat, air, and moisture. Thus, rice transportation network is suited to rail and water transportation and or 'Modal Shift.'

Currently, rural roads are a fundamental element in the provision of access in growing areas, distribution centers, and multimodal transportation. However, the infrastructure of rural roads does not suit for a number of heavy trucks. The increasing of trucks on rural roads ultimately increases road maintenance needs. Therefore, it is important to study about the multimodal transportation of rice in order to increase efficiency and maximize profit. This study aims to find the suitable method of prioritisation analysis for Department of Rural Roads to select the roads that have the economics worthiness for the road improvement plan.

2. ANALYTICAL HIERARCHY PROCESS (AHP)

Analytic hierarchy process is a measurement general theory. It can be used as a multi criteria decision making method to derive ratio scales from Proceedings of the 7th International Congress on Logistics and SCM Systems (ICLS 2012), June 7-9, 2012. Seoul, Korea paired comparisons. Analytic hierarchy process allows small inconsistency because in judging, human is not always consistent. The consistency index can be obtained from Eigenvalue, and Eigenvectors used to derive the ratio scales. In using analytic hierarchy process, the problem needs to be modelled and it requires a hierarchic or a network structure to represent the problem and pairwise comparisons to build relations in the structure. Paired comparison created on the basis of the user's beliefs, attitudes, available facts, and other attributes. Scale of relative priorities is obtained from a group that has common property in the hierarchy. The analytic hierarchy process gives scales for each level in form of ratio scales. Ratio scales needed in hierarchical weighing process.

In this study, the projects which were applied AHP theory of the Department of Rural Roads were reviewed, there were five studies as follows.

- A study on the model for controlling truck load on rural roads in 2011.
- A study and detailed design of the weighting station on rural roads in 2012
- A study of Truck Route Development Plan of the Department of Rural Roads, 2013.
- A study on goods transport network and the establishment of a truck monitoring station in the eastern region in 2014.

- A study to develop a network of goods transport on rural roads supporting the border trade in Thailand in 2014.

From reviewing the above projects, the five important factors were found and these will be compared to five factors derived from the analysis by the Structural Equation Modeling (SEM). By adjusting the weight values calculated from the five projects mentioned above which can be seen in *Figure 1*.

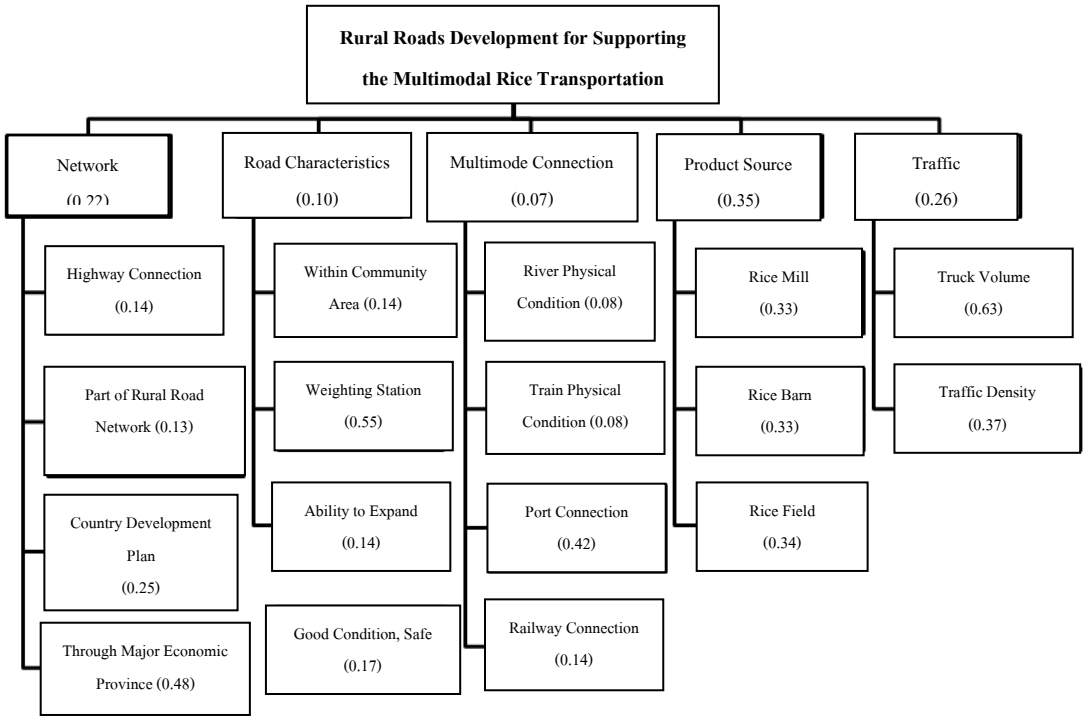


FIGURE 1 The factors and weights used for the AHP analysis in this project

From the factors and weights in *Figure 1*, they were used to calculate the net total scores of all 10 routes, as summarised in *Table 1*.

TABLE 1 Summarise of the total net score of roads from the AHP analysis

Rank	Route	Percentage (%)
1	Nakonsawan 3009	90.44
2	Ayuttaya 2008	75.02
3	Nakonsawan 3104	74.06
4	Ayuttaya 2022	65.18
5	Pathumthani 3009	60.70
6	Pathumthani 3015	60.70
7	Nakonsawan 3041	59.57
8	Ayuttaya 2005	59.29
9	Nakonsawan 3016	57.87
10	Ayuttaya 3032	57.59

3. STRUCTURAL EQUATION MODELING (SEM)

Structural Equation Modeling (SEM) is a multivariate data analysis technique that employs a variety of techniques to analyze common data. Therefore, it is possible to find the relationship and find the cause and it can also be used to analyze both observed variables and latent or unobserved variables (Kulayavanich Commanda, 2014). The advantages of the SEM are as follows.

- SEM is a method that combines the technique of finding the cause, regression analysis, the relationship of parameters, covariance and correlation which makes the SEM is both a technique for finding causes and finding relationships.
- The SEM can verify for multiple simultaneous causal equations at the same time without doing separate analysis like regression analysis technique.
- Variables in the SEM can be both independent and dependent variables.

The most widely used program for SEM are LISREL, EQS, AMOS, MPLUS, LISCOMP, etc. In this project, AMOS was used with the following elements:

- Factor or latent variable is a variable that cannot be found directly but it can be made up from observed variables.
- Observe Variable is a variable that can store data directly. It may be secondary or primary.
- Variable displays the factors and the observed variables.
- Study of the influence of the observed variables effect on the factors or the influence of factor 1 on factor 2.
- The relationship between variables.

The AMOS program is shown in *Figure 2*, with a raw data window, example of models and result displays are shown in *Figure 3 to 4* respectively.

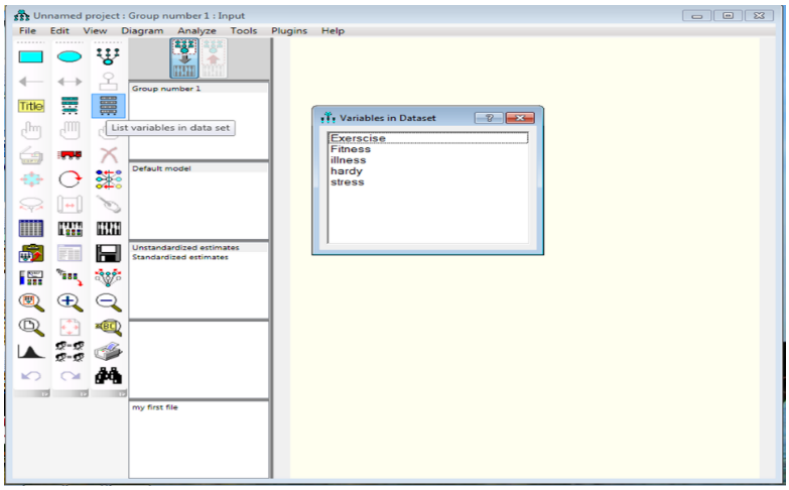
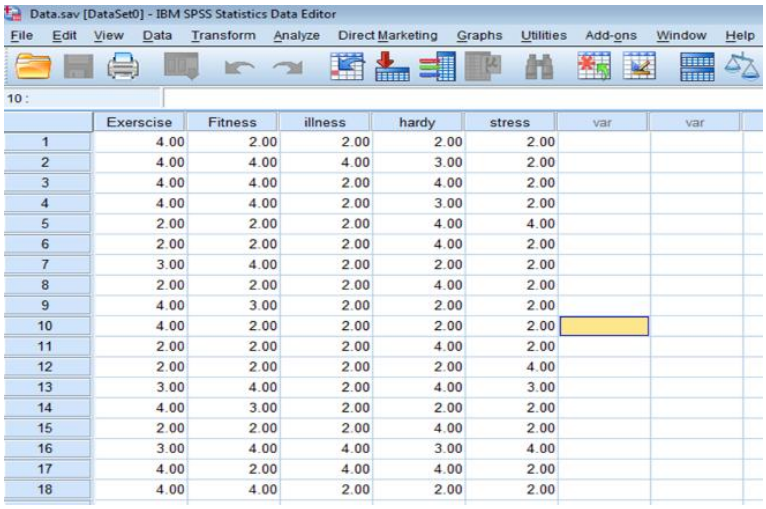


FIGURE 2 Example of AMOS Programme



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	Exerscise	Fitness	illness	hardy	stress	var	var
1	4.00	2.00	2.00	2.00	2.00		
2	4.00	4.00	4.00	3.00	2.00		
3	4.00	4.00	2.00	4.00	2.00		
4	4.00	4.00	2.00	3.00	2.00		
5	2.00	2.00	2.00	4.00	4.00		
6	2.00	2.00	2.00	4.00	2.00		
7	3.00	4.00	2.00	2.00	2.00		
8	2.00	2.00	2.00	4.00	2.00		
9	4.00	3.00	2.00	2.00	2.00		
10	4.00	2.00	2.00	2.00	2.00		
11	2.00	2.00	2.00	4.00	2.00		
12	2.00	2.00	2.00	2.00	4.00		
13	3.00	4.00	2.00	4.00	3.00		
14	4.00	3.00	2.00	2.00	2.00		
15	2.00	2.00	2.00	4.00	2.00		
16	3.00	4.00	4.00	3.00	4.00		
17	4.00	2.00	4.00	4.00	2.00		
18	4.00	4.00	2.00	2.00	2.00		

FIGURE 3 Example of AMOS Raw Data Window

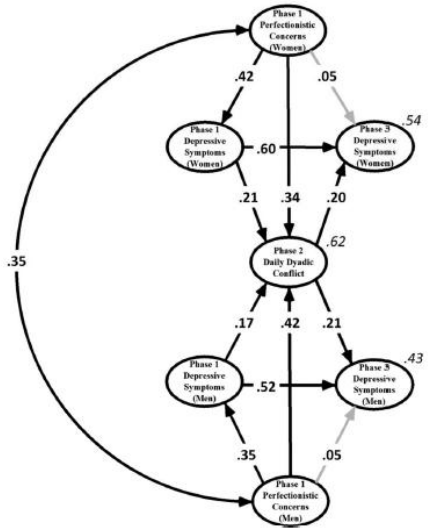

FIGURE 4 Example of diagram of SEM analysis

Parameter	*Variable*	*Estimate*	*Std. Error*	*z-value*
p3p1	exercise → fitness	0.390	0.048	8.169
P4p2	hardy → stress	-0.230	0.051	-4.559
P5p3	fitness → illness	-0.250	0.047	-5.316
p5p4	stress → illness	0.308	0.047	6.538
Variances				
varex	Exercise	1.000	0.073	13.650
varhr	Hardy	1.000	0.073	13.650
varft	Fitness	0.848	0.062	13.640
varst	Stress	0.947	0.069	13.640
e5	Illness – unexplained variance	0.823	0.603	13.640

FIGURE 5 Example of Table of result after analysis.

The process of analysing the structural equation model is as follows;

1. Study related research including relevant literature reviews.

2. Create models and assumptions.

3. Make a questionnaire

4. Data collection

5. Analyze and verify the results.

- Preliminary Analysis
- Measurement Model Analysis
- Structural Model Analysis
- Model Fit and Model Adjustment Verification.

6. Conclusion

In order to confirm that if the created model is consistent with empirical data, it can be verified by statistically which used for measuring consistency, such as

- Normal Chi-Square (CMIN / DF) should be no more than 2.00 which show that the collected data are consistent.
- Standardized Root Mean Square Residual (SRMS) values are no more than 0.05 which representing harmonic data. But if the model is large, it can be extent to no more than 0.08.
- Comparative Fit Index (CFI) values are generally greater than 0.9 as a basis for measuring the relationship between model and data.
- The Normed Fit Index (NFI) generally uses a value greater than 0.9 as the basis for measuring the harmony between the model and the data.
- Incremental Fit Index (IFI) generally uses a value greater than 0.9.
- The Tucker-Lewis Index (TLI) generally uses a value greater than 0.9 as a basis for measuring the harmony between model and data.
- The Relative Fit Index (RFI) generally uses a value greater than 0.95 as a basis for measuring.

From the study in this research, five groups of factors were derived from the analysis of the survey elements. They will be analyzed by Structural Equation Modeling method to summarise the factors influencing highway selection including the relationship between factors to develop a rice transportation network which connecting road, railway and port to accommodate more freights in the future.

The five factors then were extracted from the survey, and analyzed by the SEM method to identify the interactions and associations among those influencing factors. Theoretically, SEM consists of two models; a measurement model and a structural model.

3.1 Measurement Model

Measurement model was conducted in order to establish confidence in the correlation among five factors. It applies four modification indices, including:

- Normal Chi-Square (CMIN/DF) should be less than or equal to 2.00

- Comparative Fit Index (CFI) should be greater than or equal to 0.90
- Incremental Fit Index (IFI) should be greater than or equal to 0.90
- Root Mean Square Error of Estimation (RMSEA) should be less than or equal to 0.10

The best fit measurement model and the modification indices in this study are shown in *Figure 6* and *Table 2* accordingly. The best fit measurement model then was applied to the analysis of structural model to identify the direction of the factor influences.

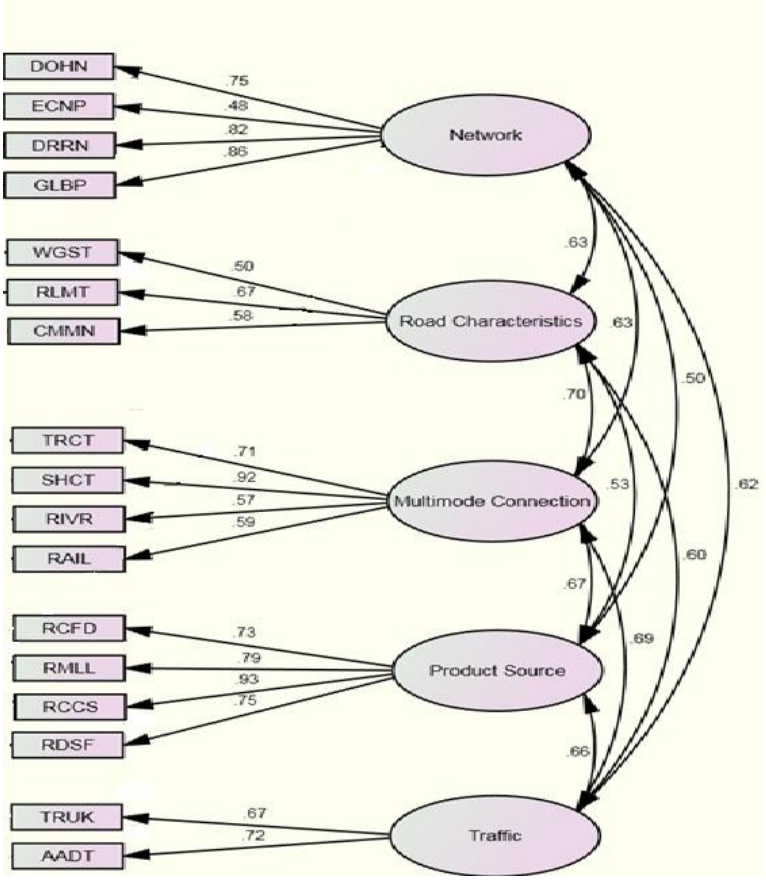

FIGURE 6 Best Fit Measurement Model

TABLE 2 Modification Indices of the Measurement Model

Modification Indices	Acceptable Range	Value
Normal Chi-Square (CMIN/DF)	Less than or equal to 2.00	**1.86**
Comparative Fit Index (CFI)	Greater than or equal to 0.90	**0.91**
Incremental Fit Index (IFI)	Greater than or equal to 0.90	**0.91**
Root Mean Square Error of Estimation (RMSEA)	Less than or equal to 0.10	**0.09**

3.2 Structural Model

Structural model was done to examine the direction of assumed relationships between the five latent variables, as reflected by the arrows connecting them. The best fit structural model and the modification indices in this study are shown in *Figure 7* and *Table 3*, respectively.

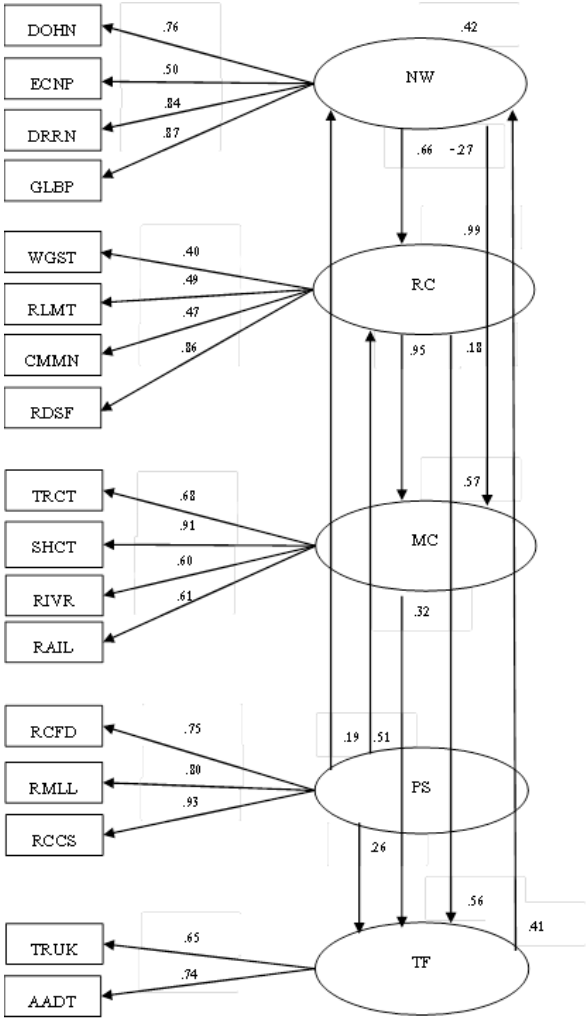

FIGURE 7 Best Fit Structural Model

TABLE 3 Modification Indices of the Structural Model

Modification Indices	Acceptable Range	Value
Normal Chi-Square (CMIN/DF)	Less than or equal to 2.00	1.79
Comparative Fit Index (CFI)	Greater than or equal to 0.90	0.91
Incremental Fit Index (IFI)	Greater than or equal to 0.90	0.92
Root Mean Square Error of Estimation (RMSEA)	Less than or equal to 0.10	0.08

According to *Figure 7*, the path coefficient among five factors including direct and indirect relationships are shown in *Table 5*. These relationships were applied to the route selection method to identify the suitable rural roads for the multimodal transportation development in the north-eastern region and the central region. Based on the results of the analysis, the Road Characteristics and Multimode Connections have a maximum coefficient of 0.95 which means the 1-unit change of Road Characteristics will affect the change of the Multimode Connection with the factor of 0.95 unit. For example, if one of the road in a community has a physical potential to develop such as widening the road, this will result in the development of interconnection to other modes of transportation, such as railway and port transportation. It also found that the Network and Product Source factors affect the Road Characteristics, with correlation coefficients of 0.66 and 0.51, respectively. Furthermore, there are also indirect relationships between the factors, such as the Network factor has direct relationship with Multimode Connection with path coefficient of 0.27 but indirectly related to Multimode Connection through Road Characteristics with path coefficient of 0.63 (Path Coefficient = 0.66 x 0.95 = 0.63).

Table 4 is show the summarised Path Coefficients between the 5 factors, both direct and indirect. These correlation values will be used in the selection of road which suitable for developing.

TABLE 4 Direct and Indirect Path Coefficient among Five Factors

	Path Coefficient										
To	**Road Network**		**Road Characteristics**		**Multimodal Transportation**		**Product Source**		**Traffic Volume**		**Total**
From	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	
Road Network	-	-	0.66	-	0.27	0.63	-	-	-	0.32	1.88
Road Characteristics	-	0.12	-	-	0.95	-	-	-	0.18	0.30	1.55
Multimode Transportation	-	0.13	-	-	-	-	-	-	0.32	-	0.45
Product Source	0.19	0.11	0.51	0.13	-	0.61	-	-	0.26	0.16	1.97
Traffic Volume	0.41	-	-	0.27	-	0.37	-	-	-	-	1.05
Total											**6.90**

4. COMPARISON BETWEEN ANALYSIS BY STRUCTURAL EQUATION MODELING (SEM) AND ANALYTICAL HIERARCHY PROCESS (AHP)

Table 5 shows the comparison of the order of analysed roads by SEM and AHP methods. It can be seen that at the first 10 roads, there are 8 corresponding roads from both analysis methods. In addition, the SEM and AHP gave the same analysis for the first three roads, which are

Nakhonsawat-3009, Nakhonsawan-3140, and Ayuttaya-2008, respectively. From the above statement, it could be concluded that the both methods give the concordance results.

TABLE 5 The first 10 roads obtained from the analysis of SEM and AHP Procedures

Ranking	SEM Analysis	AHP Analysis
1	Nakhonsawan-3009	Nakhonsawan-3009
2	Nakhonsawan-3104	Ayuttaya-2008
3	Ayuttaya-2008	Nakhonsawan-3104
4	Ayuttaya-2005	Ayuttaya-2022
5	Nakhonsawan-3041	Pathumthani-3009
6	Nakhonsawan-3102	Pathumthani-3015
7	Ayuttaya-2022	Nakhonsawan-3041
8	Ayuttaya-3032	Ayuttaya-2005
9	Ayuttaya-2039	Nakhonsawan-3016
10	Nakhonsawan-3016	Ayuttaya-3032

However, the both analyses have the advantages and limitations which are as follows.

- AHP is process of dividing primary factors into several sub-factors and the main factors and the sub-factors have different and independent weight values which allowing for more detailed analysis. However, this analysis is based on the assumption that each factor and have no correlation and the used data in this analysis come from an expert interview. Therefore, it is necessary to select those who are knowledgeable in providing information. If the information is very complex, it may affect the understanding of the interviewer.
- SEM is the process of considering the relationship of each factor by making assumption of if there is a change of one factor, it will affect the change of other factors, both directly and indirectly. This can be reflected in actual performance, however, the analysis in this way is complex and need a lot of information to make the analysis as accurate as possible.

5. CONCLUSION

It can be concluded that in this study, there are many factors which are related to each other and affect to the analysis when one of the factor is changed. For rural roads, the preferred analysis method is the Structural Equation Model (SEM) method, as it can reflect actual performance and show the relationship between all the factors. Analytical Hierarchy Process (AHP) analysis is suitable for a multi-factorized study, which makes it possible to know the importance of each of the key factors and sub-factors and the expert in the study area is also important.

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