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ANALYTICAL OF MULTI-CRITERIA APPROACH FOR IDENTIFYING THE WEIGHT AND FACTOR OF RURAL ROAD MAINTENANCE PRIORITIZATION

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ABSTRACT: The annual budget prioritization for road maintenance at the Department of Rural Roads (DRR) is now based on a comparison of the benefits of reduced road user costs and maintenance costs, which is primarily based on two factors: traffic volume and the international roughness index (IRI). As a result, the budget allocation for a low-traffic road may be inadequate. The purpose is to improve budget prioritizing by the DRR's strategic plan. Economic, engineering, and social factors are grouped into three categories. The Analytic Hierarchy Process has been used to determine the weight of each factor and the priority value of each strategic driving plan (AHP). The logistic and integrated transport systems, reducing traffic congestion in urban areas, developing transportation to strengthen competitiveness and rural economic development, and tourism are the priority values of DRR's strategic plan (in order of priority). Because it reflects the value of an investment, the economic factor is the most significant. The Engineer analyzed the priority value for IRI, V/C ratio, traffic volume, heavy truck volume, lifeline network, and connectivity to other road networks. The result of the engineering factor indicated that connecting to other road networks is a key aspect of every strategy. In the tourist strategy, IRI is the only aspect that is prioritized. Population density, tourist attractions, and business hub are all characteristics that every strategy focuses on when it comes to social factors. As a result, priority factors should be investigated the road hierarchy is consistent and appropriate budget allocation.

Keywords: Prioritization, AHP, IRI, Low Volume Road

1. INTRODUCTION

The World Bank considers roads to be important assets for reducing poverty levels and considers them to be keys to raising living standards. [1]. Better roads improve social outcomes by lowering transportation costs and fostering economic linkages that improve agricultural and industrial production while also facilitating access to public service facilities.

The Department of rural roads (DRR) in Thailand is responsible for road maintenance of 48,974 kilometers, which includes 2,563 kilometers of concrete, 45,868 kilometers of asphalt, and 542 kilometers of gravel [2]. The deterioration of pavement is in exponential function and is affected by pavement age, traffic volume, the volume of heavy trucks, rainfall, and topographical gradient [3,4]. DRR allocated funding for road network maintenance by road strategies and the nation's development policy, including strategies for logistic and integrated transport systems, tourism, reducing traffic congestion in urban areas, and developing transportation to strengthen competitiveness and rural economic development.

The annual budget for road maintenance is primarily based mostly on engineering and asset management criteria to guide investment and work to reduce life cycle agency and road user costs such as travel time, operating costs, and safety [5]. Benefit-cost analysis is used to assess the impact of various funding levels on the economic cost to users and agencies [6], as well as analyze treatment alternatives from a financial perspective. Database of existing road assets, use patterns, asset deterioration rate, project cost, user costs of deteriorated condition, and investment triggers or minimally tolerated conditions are all included in these models minimally tolerable conditions [7]. As a result, the allocated budget may be insufficient or inappropriate for maintenance needs in each area, especially the low-volume road.

The most widely known method for determining the economic value of road maintenance investments is cost-benefit analysis (CBA), which involves evaluating all of the costs and benefits of projects to determine their monetary worth. The most important monetary benefits are reduced vehicle operating costs, travel time savings, and accident reduction. Chanon and Wisanu (2009) studied the analytical framework of road serviceability level corresponding to road strategies found that the economic analysis approach is suitable for roads that accommodate high traffic volume. According to the life cycle cost analysis, an investment with an Annual Average Daily Traffic

(AADT) greater than or equal to 3,500 vehicles per day and an International Roughness Index (IRI) greater than or equal to 3.0 meters per kilometer will be effective [8]. When this criterion is compared to current AADT data from DRR, it was found that over 84 percent of roads have AADT less than 3,500 vehicles per day **(**Fig.1**)**.

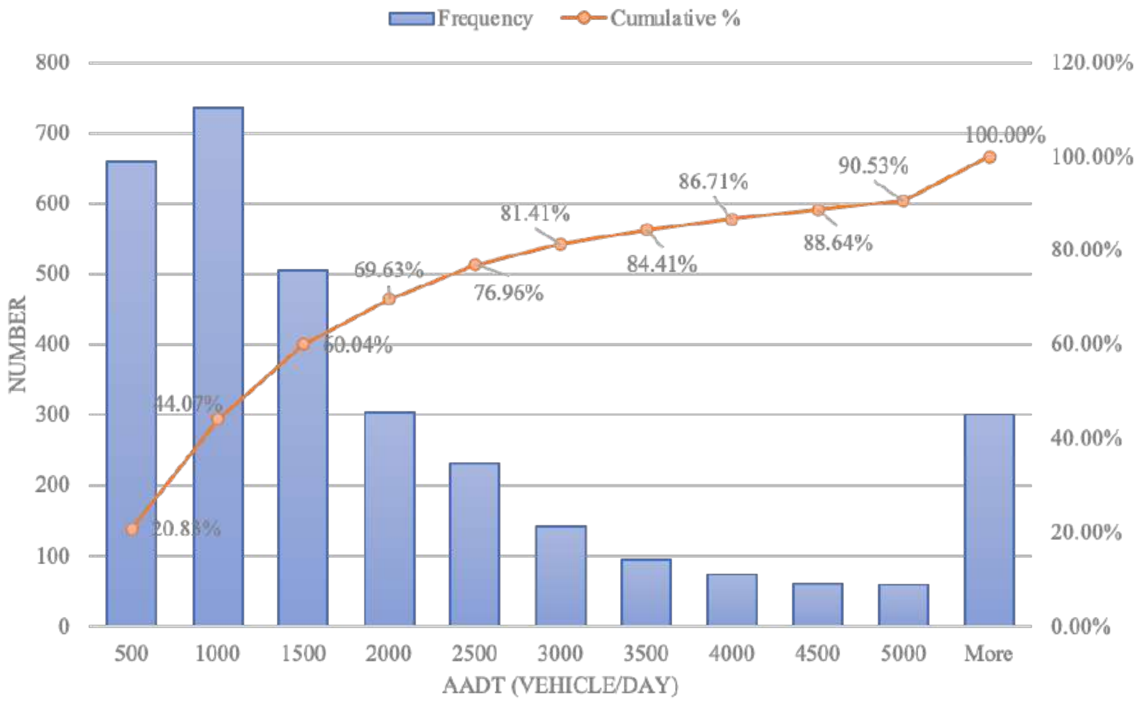

Fig. 1 Cumulative Traffic Volume of Department of Rural Road (Department of Rural Road, 2020)

The effectiveness of economic evaluation as a decision-making tool is limited to annual road maintenance budget prioritization, which is primarily based on two factors: traffic volume and the international roughness index (IRI). The benefits of low-volume roads, in particular, will not be enough to justify the benefit. Many sections of rural roads with low traffic volumes were ignored.

This paper will analyze the prioritization factor to improve budget prioritizing by the economic, engineering, and social factors using the analytical hierarchy process (AHP). As a result, priority factors should be evaluated in ensuring that the road hierarchy is consistent and appropriate, considering economic, engineering, and social factors. Moreover, it is expected that findings will assist the policymakers and agencies in developing transportation appraisal methods that are both cost-effective and beneficial to the region.

2. OBJECTIVE

The objective of the study was to use an analytical hierarchy process (AHP) to analyze the priority factors based on the Department of Rural Road's Strategic Driving Plan in Thailand, and to prioritize the main and secondary factors by considering economic, engineering, and social factors to classify the rural road network hierarchy and apply it to ranking the road sections for appropriate budget allocation.

3. A LITERATURE REVIEW

3.1 DRR’s Rural Road Characteristics

The road under the responsibility of the DRR is a network of feeder roads serving both accessibility and mobility [9]. According to the road function classification shown in Fig. 2, the DRR's road network serves as a collector. Because the roads carry traffic from local roads to arterial roads, the collector's level of service is at a lower speed and for shorter distances.

Road accessibility allows people to be connected to public facilities such as hospitals, schools, police stations, temples, and transportation hubs. Furthermore, road infrastructure contributes to a better society, such as poverty reduction and economic development. [10] Communities can develop local economies as transportation infrastructure improves, allowing them access to resources, capital, goods, and the labor market. [11] In addition, road improvements influence land use and market expansion, as well as encourage investment and employment. [12]

Fig. 2 Hierarchy of Highway System [13].

3.2 Evaluation Method for Road Investment.

The World Bank has published guidance on economic evaluation for low–volume rural roads, which looked into design and appraisal methods for rural transportation to achieve the goal of providing basic access to rural communities [14]. As shown in Table 1.

Table 1 Evaluation method for road investment.

Method	Description
Benefit-Cost Analysis	A systematic method for calculating and comparing the costs and benefits of a road. Used to evaluate an investment's economic efficiency. Effects on agency costs, maintenance costs, and road user costs.
Cost-Effectiveness Analysis (CEA)	An evaluation approach that compares the cost of interventions with their intended impacts in nonmonetary terms. CEA is used in situations where benefits are difficult to quantify.
Multicriterial Analysis (MCA)	An analysis based on perceived importance. The composite score can be used to rank road projects. MCA can be beneficial for incorporating multiple objectives as well as benefits that are difficult to monetize.

3.3 Factor to Prioritization Road Maintenance.

This study reviewed the factor that should be considered when prioritizing road maintenance, and it is divided into three groups based on the findings of a literature review. [15,16]

3.3.1 Economic factor

It is an evaluation of all of the costs and benefits of projects to determine their monetary value. The most important monetary benefits are reduced vehicle operating costs, travel time savings, and accident reduction compared with maintenance and rehabilitation cost. As a result, the benefit-cost ratio must be greater than 1.0

3.3.2 Engineering factor

It's a direct factor in the design, management, maintenance, and rehabilitation of a road, and it includes physical, functional, distress, condition, connectivity, and accident data. As an example,

- International Roughness Index (IRI). The World Bank developed the IRI in the 1980s as a serviceability index. IRI is a standardized roughness measurement used to define a characteristic of the longitudinal profile of a traveled wheel track. The commonly recommended units are meters per kilometer (m/km). [17]
- Traffic Volume and Volume of Heavy Truck. It is abbreviated AADT and is the total volume of vehicle traffic on a road for a year divided by 365 days.
- Volume Capacity Ratio (V/C Ratio). It measures the level of congestion on a roadway by diving the volume of traffic by the capacity of the road.
- Lifeline Road. It is a way of transportation for which there is no substitute or for which the substitute requires a significant increase in time or money. It has a significant impact on a community's social or economic viability, especially in a disaster situation. [18]
- Connectivity to the road network. It represents the significance of a road about the existing road network, which may include national highways, state highways, rural roads, and local roads.
- Accident Data.

3.3.2 Social factor

It's a direct factor that is related to social, environmental, land use, community area, and attractive point of Interest within 2 kilometers on both sides of the road. As an example,

- Population density.
- Tourist spots.
- Government office, School, Colleges, and Hospital.
- Business Center, Market.
- Industrial area, Warehouse

3.4 Analytical hierarchy process.

The analytic hierarchy process (AHP), also known as the analytical hierarchy process is a structured method for organizing and analyzing complex decisions that are based on math and psychology. It was created in the 1970s by Thomas L. Saaty [9] and it has been extensively studied and refined since then.

It is a precise method of quantifying the weights of decision criteria. Pair-wise comparisons are used to estimate the relative magnitudes of factors based on individual experts' experiences. Using a specially designed questionnaire, each respondent compares the relative importance of each pair of items.

AHP is suitable for complex decisions involving the comparison of difficult-to-quantify decision elements. It is based on the assumption that when challenged with a complex decision.

Saaty suggested an arbitrary rating scale of 1 to 9 based on psychological experiments commonly used in questionnaire surveys. The definition of each scale is as follows:

1: Two criteria are equally important.

3: Moderate importance of criterion X over criterion Y.

5: Strong importance of criterion X over criterion Y.

7: Very strong importance of criterion X over criterion Y.

9: Extreme importance of criterion X over criterion Y.

2, 4, 6 &8: Intermediate value between the values mentioned above

With these rating values as elements of matrix a_{ij} of the criteria i and j (where a_{ij} are the geometric mean value of responses), a pairwise comparison matrix A has been developed as follows Eq. (1)

$$\mathbf{A} = \begin{bmatrix} \mathbf{1} & \mathbf{a12} & \dots & \mathbf{a1n} \\ \frac{\mathbf{1}}{\mathbf{a12}} & \mathbf{1} & \dots & \mathbf{a2n} \\ \dots & \dots & \dots. & \dots \\ \frac{\mathbf{1}}{\mathbf{a1n}} & \frac{\mathbf{1}}{\mathbf{a2n}} & \dots & \mathbf{1} \end{bmatrix} \quad (1)$$

4. ANALYSIS

This research is a study on the strategic, main, and secondary factor analysis based on the Department of Rural Road's Strategic Driving Plan in Thailand. The methodology of research was an analytic hierarchy process that compared each pair of factors in a matrix table. An analysis calculated the priority value for the economic factor in terms of a benefit-cost ratio, the engineering factor included IRI, V/C ratio, traffic volume, the volume of heavy truck, lifeline network, and connectivity to other road networks. Finally, social factor is the number of people, tourist attractions, business centers, government offices, hospitals, and industrial areas were all counted along both sides of the road for 2 kilometers.

The population was purposive in the authority of budget planning and prioritization on road maintenance or decision–making authority on planning policy, which is 20 respondents.

In AHP, the criteria are synthesized to a different level of the hierarchy. The decision's primary objective is at the top level. The criteria which were used to make this decision are on a lower level. In the second level, three major criteria are considered: economic, engineering, and social factors. Engineering and social factors are synthesized into seven and six sub-criteria, respectively, at the third level. The decision hierarchy for multi-criteria evaluation is given below in Fig. 3

4.1 Analysis of Priority Strategic Factor.

According to an analysis of priority strategic factors as a component of road maintenance budget allocation, the highest priority value with a priority value of 27 is strategic for logistic and integrated transport systems and strategies for reducing traffic congestion in urban areas. Second, with a priority value of 24, strategic for developing transportation to strengthen competitiveness and rural economic development, and finally, with a priority value of 22, strategic for tourism.

4.2 Analysis of Priority main and secondary Factors.

An analysis of main and secondary factors is a result of priority factors of economic, engineering, and social factor, including a secondary priority factor of engineering and social perspective. As shown in Table 2

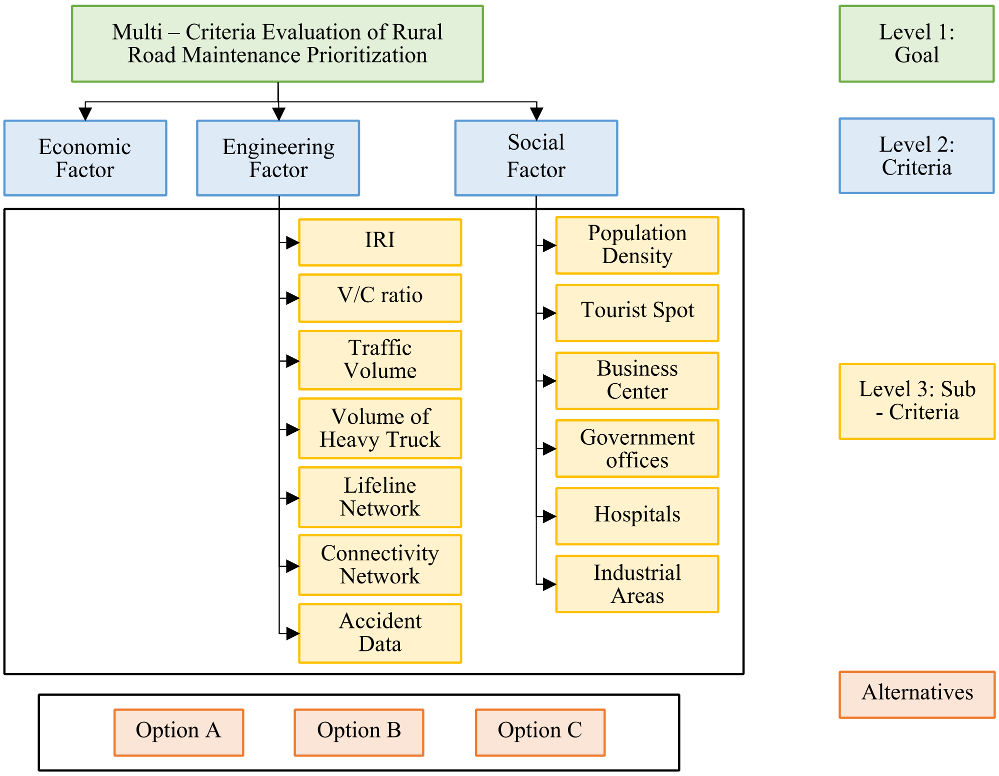

Fig. 3 Multi-criteria evaluation by AHP.

Table 2 Summary of the analysis of Priority Factor.

Factor/Strategic	LIS Priority Value	TCA Priority Value	TSM Priority Value	CED Priority Value
	27	**27**	**22**	**24**
Economic	**46**	**40**	**43**	**45**
Engineering	**29**	**28**	**23**	**20**
IRI	-	-	13	-
V/C Ratio	17	24	21	17
Traffic Volume	19	21	16	15
The volume of Heavy Truck	21	-	-	-
Lifeline	-	-	-	14
Connectivity to the road network	23	24	25	27
Accident data	20	31	25	27
Social	**25**	**32**	**33**	**35**
Population density	19	29	17	25
Tourist spots.	18	20	40	26
Business Center	23	26	23	27
Government office.	-			-
Hospital	-		20	-
Industrial Area	40	25		22

4.2.1 Strategic for logistic and integrated transport systems. (LIS)

The highest priority factor is the economic factor, which has a priority value of 46, followed by the engineering factor, which has a priority value of 29. In descending order, the secondary factors are connected to the road network, heavy truck volume, accident data, traffic volume, and V/C ratio.

Industrial area, population density, and tourist spots are the priority secondary factors in descending order, with a social factor having the lowest priority value of 25. As shown in Fig. 4

4.2.2 Strategic for reducing traffic congestion in urban areas. (TCA)

The highest priority factor is the economic factor, which has a priority value of 40, followed by a social factor, which has a priority value of 32. In descending order, the secondary factors are population density, business center, industrial area, and tourist spots.

An engineering factor is the lowest priority value of 28 with a priority secondary factor are in descending order is accident data, V/C ratio, connectivity to the road network, and traffic volume. As shown in Fig. 5.

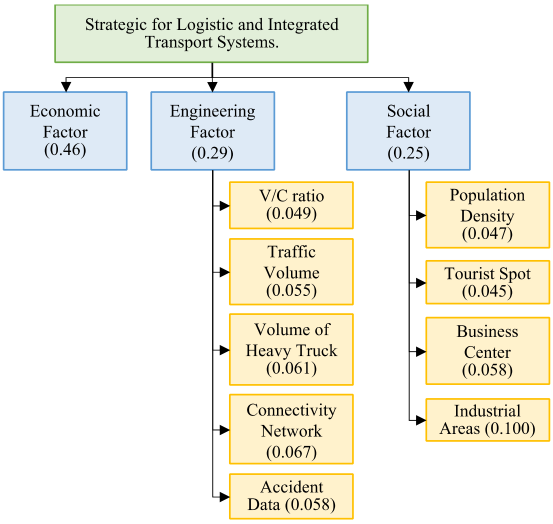

Fig. 4 A hierarchy structure for evaluation of strategic logistic and integrated transport systems.

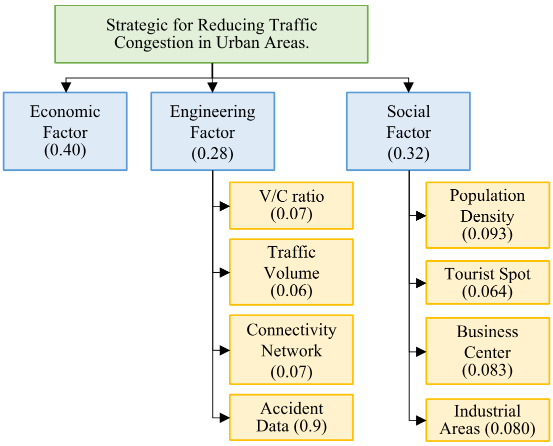

Fig. 5 A hierarchy structure for evaluation of strategic for reducing traffic congestion in urban areas.

4.2.3 Strategic for tourism (TSM)

The economic factor is the highest priority value of 44 and 33 for social factor with a priority secondary factor are in descending order is tourist spots, business center, hospital, and population density.

Accident data, connectivity to the road network, V/C ratio, traffic volume, and IRI are the priority secondary factors in descending order, with an engineering factor being the lowest priority value of 23. As shown in Fig. 6.

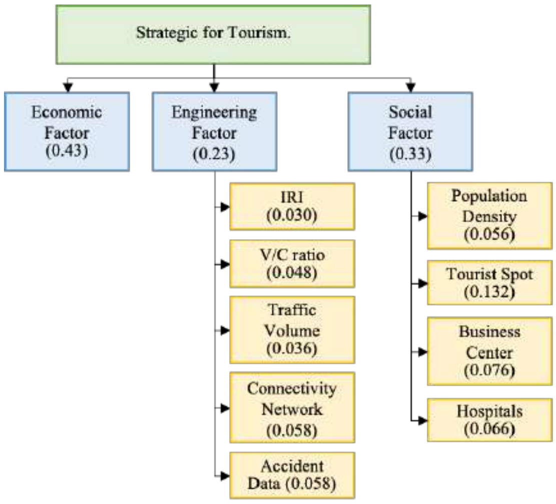

Fig. 6 A hierarchy structure for evaluation of strategy for tourism.

4.2.3 Strategic for developing transportation to strengthen competitiveness and rural economic development (CED)

Economic is the highest priority factor same as other strategic with a value of 45, followed by the social factor, which has a priority value of 35. In descending order, business center, tourist spots, population density, and industrial area.

Accident data, connectivity network, V/C ratio, traffic volume, and lifeline road are the priority secondary factors in descending order, with a social factor having the lowest priority value of 20. As shown in Fig. 7.

5. DISCUSSION AND CONCLUSION

The Thai government has allocated funding for road network maintenance by road strategies and the nation's development policy, including strategies for logistic and integrated transport systems, tourism, reducing traffic congestion in urban areas, and developing transportation to strengthen competitiveness and rural economic development. The DRR annual budget prioritization for road maintenance is now based on a comparison of the benefits of reduced road user costs (Vehicle Operation Cost, Value of Time, and Accidental Cost) and maintenance costs, which is mainly based on two factors: traffic volume and international roughness index (IRI). As a result, the budget allocation for these factors may be inappropriate for a low-traffic road.

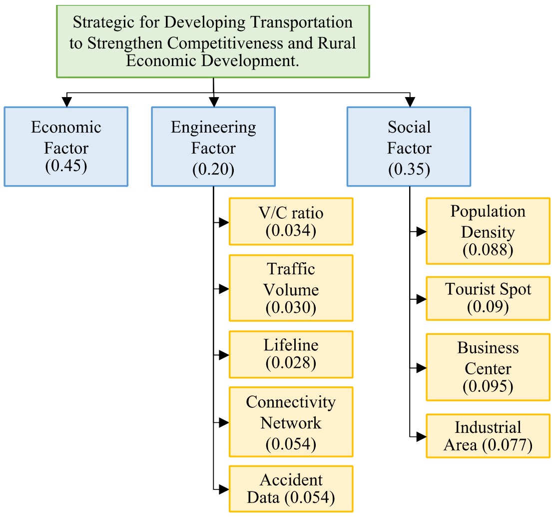

Fig. 7 A hierarchy structure for evaluation of strategies for developing transportation to strengthen competitiveness and rural economic development.

The benefits of low-volume roads may be insufficient to justify the investments. There are various other socioeconomic benefits associated with the development of the rural road. These are advantages related to increased economic activity in terms of connectivity, accessibility, regional growth, and a key component of rural development, such as access, which is important both for goods movement and labor markets and is a contributing factor to higher income. The budget allocation should be based on the Strategic Driving Plan of DRR. As a result, priority factors should be investigated and evaluated so that road hierarchy is consistent and appropriate, considering economic, engineering, and social factors.

This research is a study on the strategic, main, and secondary factor analysis based on DRR's Strategic Driving Plan. The methodology of research was an analytic hierarchy process that compared each pair of factors in a matrix table. According to an analysis of priority strategic factors, the highest priority value is strategic for logistic and integrated transport systems (LIS) and strategies for reducing traffic congestion in urban areas (TCA). Second, strategic for developing transportation to strengthen competitiveness and rural economic development (CED) and finally, strategic for tourism (TSM).

The economic factor is the most important factor that every strategy considers because it reflects the value of an investment. In terms of social factors, TCA, CED, and TSM are secondary considerations because it's a factor that reflects the land use, social characteristics, and usage behavior. However, LIS is the only one with secondary engineering factor significance.

The engineering factors found that connectivity to other road networks is an important factor in every strategy because it provides network connectivity and ensures traffic continuity. transporting goods and services and making public services and attractive places more accessible. Accident data is the primary-secondary factor that almost every strategy recognizes. The V/C Ratio is a secondary priority factor because it is related to the quality of traffic flow and congestion, particularly in urban areas.

Finally, secondary social factors indicated that all strategies prioritize consistent and appropriate road usage behavior, for example, LIS prioritizes industrial areas. Population density is considered important for TCA. The number of tourist spots was emphasized in TSM. The importance of business centers is strategically valued for CED. Furthermore, it was found that the second factor in population density, tourist spots, and business center is a factor that every strategy prioritizes, but the order of each strategy differs.

Following a detailed analysis of main and secondary factors in each strategy, LIS is the only one that prioritizes the volume of the heavy truck as the most important component. Because roads of that strategy support the transportation of goods and services, as well as connectivity to other networks. Because routes enhance the growth of transportation of services and goods while also connecting to other networks. As a result, to develop spatial logistics management, network creation, and the connectivity of raw materials source, production base, and market to improve and increase logistics and supply chain management.

Furthermore, to decrease transportation costs and improve the efficiency of transportation services, as well as to integrate the logistic network, such as roads, rails, waterways, and air, and to strengthen the private sector's competitiveness. Furthermore, a business center and industrial area are also priority factors in the social secondary factor. Finally, according to the third Thailand logistic development plan (2017-2022) of the office of the national economic and social development council, road asset management is a priority factor in the strategy of logistic and integrated transportation systems to be more efficient.

Moreover, TSM as an important service sector, develop transportation facilitation toward the tourist attraction and create value-added products and travel service and is the only one that prioritizes IRI as a maintenance management factor. Because the tourist road network must be maintained to ensure that it remains in good condition, is comfortable, and is conveniently accessible to tourist attractions. Furthermore, the tourism strategy's network has a significantly high traffic volume exclusively during only the festival season or the vacation. Hospital is a secondary priority value for social factors in tourism strategy. There is a possibility and risk of an accident during the vacation season due to the high volume of traffic and increasing travel speed. Assemble the engineering factor, which prioritizes the accident data, reflects the importance of being consistent and heading in the same direction that can respond to sustainable and environmentally friendly tourism.

Private car ownership and road usage are increasing faster in urban areas and large cities than in rural areas. This implies significant traffic congestion in many large cities, as well as air pollution and car emissions. As result, the population density, business center, and industrial are the most significant social factor in TCA. As a result, integrating the v/c ratio, accident data, and connectivity to the road network with traffic management and maintenance management in metropolitan areas may be more effective. These characteristics can help to reduce traffic congestion and make travel more convenient and safer.

According to the priority analysis of CED, the roads network in this strategy is a low-volume road, but it has a variety of other socioeconomic benefits associated with its development. These are benefits related to increased economic activity in terms of connectivity, accessibility, regional growth, and a key component of rural development, such as public service access, which is important for both goods movement and labor markets and is a contributing factor to higher income. Finally, the priority value of each factor that was analyzed by AHP was used to calculate the score and order of each road by considering economic, engineering, and social factors to classify the rural road network and apply it to appropriate budget allocation. Details of priority analysis of social and engineering factors are shown in Fig. 8 and Fig 9.

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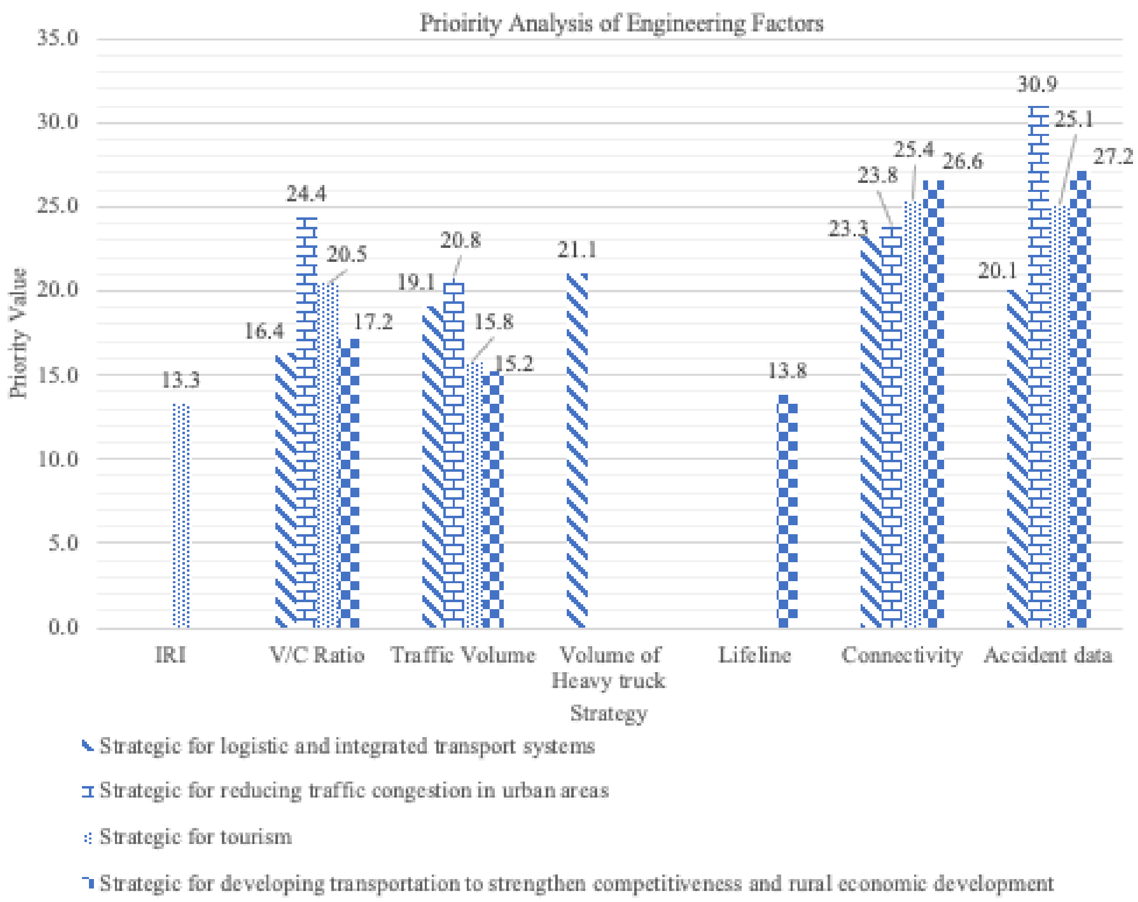

Fig. 8 Priority analysis of Engineering factors

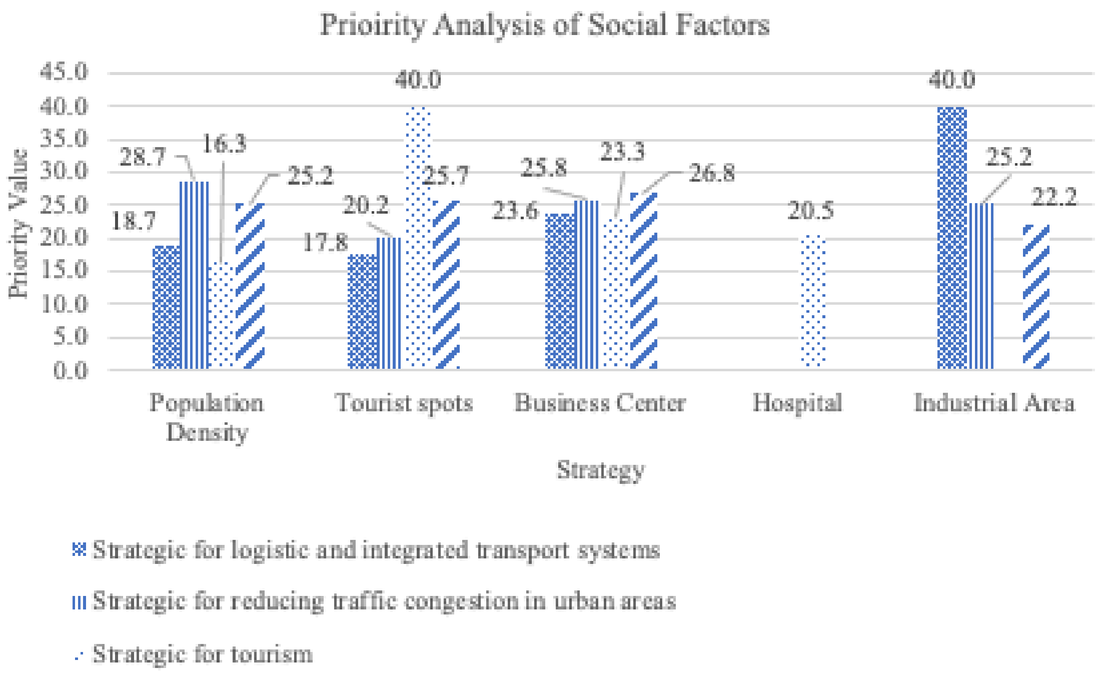

Fig. 9 Priority analysis of social factors

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