Research Article

International Journal of Advanced Technology and Engineering Exploration, Vol 11(112)
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
http://dx.doi.org/10.19101/IJATEE.2023.10102467

Multi-criteria analysis for the best route selection of resilience hinterland connection: a case study of South Sumatra province, Indonesia

Nobel Nawawi[1], Erika Buchari[2*], Joni Arliansyah[2] and Decky Oktavian Syah[1]
PhD Research Scholar, Faculty of Engineering, Sriwijaya University, Palembang, South, 30139, Indonesia[1]
Professor, Department of Civil Engineering, Faculty of Engineering, Sriwijaya University, Palembang, 30139, Indonesia[2]

Received: 26-October-2023; Revised: 20-March-2024; Accepted: 21-March-2024

Abstract
The South Sumatra province faces several challenges in maintaining a resilient hinterland connection due to high rates of road damage. National roads are dominated by heavy vehicle mix, which reaches 64% and leads to road congestion caused by over-dimension over-loading vehicles. In addition, the province's lowland geography and high rainfall lead to some roads being submerged during the rainy season. There are also inconsistencies in handling standards between national, provincial, and local roads which pose challenges for road usage. To address these issues, a multi-criteria analysis (MCA) was conducted, which resulted in a new method replacing the pavement management system (PMS) with a global road management system (GRMS). The research also identified criteria for the road management system, with transportation receiving the highest score of 3.76. This suggests that, among the stated criteria, transportation mobility is still the most important factor in assessing the performance of the road network. The analysis produced new criteria, including technique, transportation, economy, and ecology, with the best route being Route Lampung-Oku-Palembang, which received a score of 3.85 and was deemed a top priority.

Keywords
Hinterland connection, Resilience, Multi-criteria analysis, Global roads management system.

1.Introduction
South Sumatra province, located in Indonesia, is renowned for its abundant natural resources and varied economic activities, which include mining, agriculture, and manufacturing. The province plays a pivotal role in supporting the national economy by producing coal, palm oil, rubber, and natural gas[1]. However, to ensure efficient movement of goods and people, a well-connected transportation network is crucial, especially for establishing robust hinterland connections [2]. The remote regions of South Sumatra province, particularly its hinterlands, frequently suffer from inadequate transportation connectivity, which hampers economic growth and access to markets. Furthermore, the connectivity issues in the hinterlands of South Sumatra's province are exacerbated by high levels of road damage, heavy traffic volume with overloaded trucks, and severe traffic congestion [3]

*Author for correspondence

There is a high concentration of settlements and community activities along national roads, leading to severe congestion and road damage. These issues significantly impact the cost of transportation [4].

The transportation network in the hinterland region is made up of various types of roads. National roads are only 8% of the total network, but they have a good condition rating of 92.81%. On the other hand, regional roads consist of 92% of the network, but they have a lower condition rating of 68.49% for provinces and 58.8% for districts/cities [5].

The rapid urbanization and economic growth in South Sumatra province have led to a rise in traffic congestion, especially in urban areas and major transportation corridors. Settlements have developed along the roads, and community activities that use the roads have increased, contributing to environmental problems. According to Karuppana and Krishnamurthy [6] congestion hurts the efficiency of transportation systems. As cities grow and human activity, along with the number of vehicles, increases, the quality of ambient air changes [7]. Investing in transportation infrastructure upgrades and developing traffic management strategies can alleviate congestion and improve resilience.

The current road handling program for existing roads is solely based on the integrated roads management system (IRMS) approach and the province/district roads management system (RMS). It is a set of procedures used to collect, analyze, maintain, and report pavement. Meanwhile, Tamin [8] has stated that the development of a regional transportation system should refer to good spatial planning and economic development. This approach would increase the carrying capacity of the area-wide and urban infrastructure.

The province of South Sumatra is prone to frequent flooding due to its geographical characteristics, which include river basins and heavy rainfall. These floods can cause damage to roads, bridges, and other transportation infrastructure, leading to disruptions in the movement of people and goods. One road section, the Palembang-Sekayu-Lubuklinggau national road route, experiences high levels of damage from floods and landslides. This is because most of the road stretches down the Musi River, making it susceptible to submersion during periods of high rainfall.

According to data from Balai Besar Jalan Nasional Regional 7 Sumatra Selatan, heavy vehicles dominate the daily traffic on the main routes in South Sumatra province. Specifically, the Palembang-Betung-Jambi route has a percentage of 64.14% of heavy vehicles, while the Palembang-Lubuklinggau route has 62.2%. On average, the National Road section has a percentage of 54.04% of heavy vehicles. This data highlights the significant proportion of heavy vehicles using these roads in South Sumatra. The source of this information is the extension of the Directorate General of South Sumatra highways. Karami et al. [9], have stated that overloading on roads can lead to increased damage to the road, which in turn can affect the reliability and service levels of the road. This can result in longer travel times, disruption of connectivity, and reduced capacity, ultimately leading to higher transportation costs and a negative impact on the economy.

Extensive research has been conducted on measuring resilience and its use in infrastructure management decision-making. Chen et al. [10] and his team have created a measurement model which aims to achieve maximum performance in terms of resilience levels, total container request time, maximum transport, and port capacity. This model is applied in the context of the Port hinterland container network (PHCTN).

Miller-Hooks conducted disaster simulations using 100 surface area attributes of transportation systems that affect their resilience to disasters. Imran et al. [11] have pointed out that a transportation system can have a major impact on a community's resilience to disasters. They have identified six key dimensions of transport infrastructure resilience, namely engineering, infrastructure services, ecological, social, economic, and institutional. These dimensions are measured using qualitative and quantitative indicators based on the proposed transportation resilience indicators framework (RIF).

The current methods of measurement for road infrastructure performance only focus on specific systems and don't provide a comprehensive overview that integrates regional land use, economics, and environmental aspects. Therefore, this research aims to provide an overview of the road network's performance, particularly its connection to the hinterland in South Sumatra province, as part of an integrated planning approach that considers various aspects and stakeholders. It's important to conduct more comprehensive research in the future that combines various factors, including pavement structural conditions, transportation service quality, regional economic growth, and environmental considerations.

Reliable resilience is essential when geo-disasters affect the environment, urban habitats, building construction, lifelines, infrastructure, and lifecycle [12].Transportation systems within infrastructure networks need to be designed with resilience against disaster and disruption. This is typically accomplished by carefully planning the network’s topology and features [10]. Efficient transportation facilities like roads and railways play an important role in the distribution of local products to regional and national markets [13]. Efficient connectivity also supports trade and export activities, as locally produced goods can be easily transported to ports for export to international markets [14].

The main challenge in South Sumatra is the connectivity gap in the hinterland. The lack of well-organized network systems, transportation systems, and activity systems has hindered the improvement and management of infrastructure to maximize economic potential and natural resources. To address this issue, a study is being conducted to develop a comprehensive framework for selecting the best routes that will enhance the resilience and overall connectivity of the hinterland regions in the province. The results of this research are expected to help in informed decision-making, sustainable development, and improved quality of life for the communities living in the hinterland areas of South Sumatra. The study will provide valuable insights to policymakers, transportation planners, and stakeholders to improve state connectivity, foster economic development, and build resilient transportation infrastructure.

This paper proposes three levels of contribution - academic, strategic, and operational, to improve the performance of road transport networks during disruptive events. We identify the resilience characteristics that influence the impact of different types of disruptive events at different levels and develop resilience indices to measure the overall resilience level of road transport networks. Finally, we aim to develop an integrated road network system to increase the resilience of the road transportation network.

The research is motivated by the gaps and challenges in the existing literature. It aims to provide a comprehensive, multidimensional analysis that integrates all important aspects.

1.1Problem formulation

Based on the issues mentioned above, this study aims to address the following questions:

- How can we establish criteria and sub-criteria for evaluating the performance of the road network in South Sumatra?
- How can we identify the priority routes for road network development that will facilitate heavy freight transportation and support regional growth in South Sumatra?
- What are the recommended policies for managing road infrastructure in South Sumatra?

1.2Research objectives

- To establish criteria and sub-criteria for evaluating the performance of the road network in South Sumatra.
- To identify the priority routes for road network development for heavy transportation in supporting regional development in south Sumatra.
- To make a policy recommendation for the maintenance of road infrastructure in south Sumatra.

The outline of this paper is as follows. Section 1 explains about background, problem formulation, research objective, and motivation of this paper. Section 2 covers the literature study. Section 3 explored the methodology in detail. Section 4 presents research details. Section 5 describes the discussion related to the results obtained. Finally, it is concluded in section 6.

2.Literature study

2.1Resilience in transportation

Resilience is a term that comes from the Latin word “resiliere”, which translates to “bounce back” or flexibility [15]. The concept of resiliency was first introduced in 1973 by Holling in the context of ecosystems. Holling showed that resilience refers to the system's ability to handle change and the unexpected, and to what extent the system can change without becoming unacceptable [16]. Another ecological concept is the principle of vulnerability and adaptability, which is closely related to resilience. These concepts have become dominant in assessing and analyzing social and ecological systems when disturbances and changes are identified as the main constraints [17]. In engineering, resilience is a system designed for durability, efficiency, and predictability. In contrast, ecological resilience comes in the form of interventions that maintain the system's ability to absorb changes from numerous services [18]. Resilience takes two forms. Vulnerability characteristic is a negative aspect of resilience, while adaptability is a positive characteristic [19].

The term "resilience" has been introduced into various fields such as economics [20], social science by Barnett [21], and systems science and engineering [22] Woods [22] describe a concept and percept about resilience engineering. This concept has also been introduced and further developed in the transportation sector, especially in recent years.

In transportation engineering some of the definitions developed on resilience where resilience is expressed as:

- How the system maintains the level of service or returns itself to the service level within a certain time[23].
- Attributes reflect the ability to operate effectively in diverse and unconventional circumstances, recovery duration, and the extent of support needed for a return to the original state [24].

- Resilience is a vulnerability that can be seen as a system characteristic of the opposite side of resilience adaptability is on the other system [19].

The concept of a hinterland connection route refers to the development and management of transportation network systems that connect hinterland areas (inland or remote areas) with economic centers or ports. The development of hinterland connections is not only about accelerating the distribution of goods and supporting economic growth in remote areas but also expanding hinterland and competition among ports [25].

2.2Measuring resilience

Measuring resilience can be done using two approaches. One is through a conceptual framework, also called a qualitative framework, and the other is a metric or indicator approach through more detailed analysis and modeling [21]. To find out how resilient something is, measure resilience to find out how likely the system is to collapse under external pressure and how quickly the system can recover is needed [26], improving resilience begins with good planning to reduce vulnerability and increase adaptability. Parameters for measuring resilience can be identified by employing modeling techniques based on the mode of transportation and mathematical methodologies used for quantifying resilience [27].

Preliminary studies related to disruptions to the road network have been defined as road network vulnerabilities. Berdica and Mattsson [16] elaborates further that the reliability of the road network includes three main aspects namely (1) reliability of connectivity as a certainty of achieving the goals set; (2) the reliability of travel time, the certainty of time to achieve the objectives set; and (3) reliability of capacity, the probability of the network to meet the volume of traffic at a given service level.

Transportation is a reflection of urban characteristics, but often urban development and expansion make transportation systems complicated, and vulnerable to disruption of transportation services and negative aspects [28]. Assessing urban infrastructure resilience involves three key aspects: technical elements throughout the life cycle, economic integration into the recovery process, and effective social and organizational measures during the operational and management phases [29].

The concept of resilience in integrated urban transport refers to performance in the face of external shocks and the ability to continuously provide transport services of all modes. Resilient transportation is a goal in the pursuit of transportation sustainability [30].

Wang [19] explain that disruptions in conditions occurring on the transportation system can be divided into three categories: Disasters; Various daily events under demand capacity; and sustainable change in the long term. While disasters are infrequent, their occurrence inflicts substantial damage on the system, leading to prolonged recovery periods. In contrast, more frequent events like traffic accidents or heightened activity result in diverse fluctuations in capacity and demand. Furthermore, the disruption event that occurred at first may not be noticeable in its impact, but it will affect us slowly for the masses to come. A novel measurement approach has been devised to quantitatively assess both the system resilience and node resilience within transport infrastructure networks, utilizing the distinctive characteristics of network diversity [31].

Anticipation for disturbance, a resilient transportation system has several qualities such as (1) efficiency in recovery from disasters; (2) reliability level through connectivity, capacity, and travel time; (3) economically, environmentally, and socially sustainable. Jenelius and Mattsson [18] stated that enhancing the resilience of the road network requires ensuring ample route options for all destinations. The availability of route choices is crucial, particularly in emergencies, and concurrently serves as an added capacity to enhance road services. Resilience is defined as the ability of the system to recover from disaster, prepare for further disruption, and have a backup system to be able to maintain services at critical times [32].

The decrease in the quality of infrastructure services after a disaster needs immediate treatment, but often in a short time, it is not possible to make immediate replacements a standard resilience model, and disaster management is needed to anticipate early conditions of disaster [33]. Develop resilience measures to measure temporal and spatial variations in infrastructure capabilities in recovery after a disruption event. The proposed formulation has a hierarchical structure that allows good utilization of available data at lower hierarchical levels to improve the predictive capabilities of models at the infrastructure level [34] Increasing disruption and deterioration in service quality will also affect the supply chain, especially for small and medium enterprises [35].

In the context of disruptions arising from outside, as well as conditions during COVID-19, it shows that there is a close relationship between individual and physical resilience to organizational resilience, in this case, the role of the government [36]. Recovery is strongly influenced by the government's response and management.

Regional transportation planning faces several complex problems due to the diversity of transportation systems. There is a limit to the authority between central, provincial, and district governments. At the very least, decisions taken should reflect a synergy where regional aspirations are aligned with the needs of the province and central government. In addition, technical obstacles must be considered, such as travel needs and differences between load loads and road standards, which ultimately affect construction costs, travel time, and accessibility between regions [8].

2.3Multi-criteria analysis (MCA)

The MCA is a method used to assess and simplify complex decision-making processes. It is particularly useful when numerous systems need to be measured, whether they are measurable or immeasurable. However, the complexity of decision-making with multiple criteria and goals can make it challenging to create logical frameworks [37]. In the case of road network systems, a participatory approach was used to develop the system. This approach involved bottom-up planning, which means that stakeholders participated in the decision-making process and their wishes were taken into account [38]. One approach used is AHP, which allows comparing alternatives against a fuzzy set of defined criteria [39].

The MCA process can be broken down into five simple steps that help in deciding:

- Determine the target: Decide the desired goal in the decision problem.
- Define criteria: Identify the variables or criteria that will be used in the analysis.
- Weight criteria: Assign a weight or priority to each criterion.
- Make judgments: Evaluate the alternatives against each criterion.
- Determine/Recommend: Choose the alternative that best fits the goals and criteria that have been set.

MCA uses various approaches that differ in terms of computational complexity, level of stakeholder engagement, and timing and data needs. MCA helps with objective decision-making by allowing the selection of objective variables and open criteria. It also allows the process to be carried out openly for all interested parties.

The (MCA) method is widely used in solving problems related to infrastructure. Infrastructure issues are a typical decision-making problem because they involve many stakeholders and require multiple perspectives [40].

2.4Pavement management systems (PMS)

In the beginning, traditionally, road maintenance was related to the maintenance of road pavements, more economic resources were devoted to intervention in the decision. Decisions are assumed based on the operator's assessment of physical conditions so often the information obtained is not complete and not by planning conditions [41]. The following year road management began using the PMS by trying to rationalize the choice, where the PMS is applied to a set of procedures that are used as tools for the collection, analysis, maintenance, and reporting of pavement data. The PMS is designed as a real information system and useful data for road development and planning [41].

2.5Roads management system (RMS)

Preserving the road network is not about pavement maintenance only. It also involves addressing the quality and comfort of road users. Road maintenance gives rise to the RMS, When adopted RMS introduces a crucial objective, to enable users to travel the route pleasantly and securely [42, 43].

Ensuring the preservation of the road network goes beyond pavement maintenance. It also involves addressing the quality and comfort of road users. Road maintenance gives rise to the RMS which, when adopted, introduces a crucial objective, to enable users to travel the route pleasantly and securely. The road asset management system (RAMS) is an engaging process designed to evaluate the overall performance of the entire road network and present it in a dynamic database format [44]. The road maintenance system implementation involves:

- Roads Inventory: Formulate the entire network using database paths.
- Road funding: Looking for maintenance strategies that can optimally support the economy,

- Develop road maintenance programming: Planning and scheduling road maintenance activities and tracking the progress.
- Road safety: Monitoring road safety conditions and identifying areas where improvements are needed[45].

The need for RMS varies depending on the size and complexity of the road network being managed [45].

2.6Global roads management system (GRMS)

It was a new perspective where road maintenance alone was not enough. This concept places the road as part of the territory. Sustainable development will be widely developed to support regional development and social, economic, and environmental programs. Therefore, the improvement of the road system network must consider not only the interests of road users but also the urgency of users of the territory. A new maintenance system must be required for road planning and handling, not only to add value to the quality of life of road users but also to give more aspects to the spatial planning of the area: this is known as the GRMS [46].

Key benefits of the GRMS include improved road safety, reduced travel time, and increased economic growth. By providing reliable road data, decision-makers can make more informed decisions about planning and managing road infrastructure. This can result in better road conditions, better traffic flow, and increased economic activity in the region through an infrastructure investment approach [47]. The GRMS approach is used for strengthening analysis by further developing technical aspects to optimize the road system and placing the road system as part of land use planning.

3.Methodology

3.1Research design

The research is done by the following step as in *Figure 1*. The analysis begins by defining the transportation problems encountered and establishing the expected outcomes, gaps problems encountered in the field, the data, and the analysis needed to determine the best route in the hinterland connection.
This research analyzed road handling policies in South Sumatra province, using a MCA method. Criteria and sub-criteria were obtained from road operators, experts, and users. The research aimed to formulate strategic policies, prioritize road-handling programs and increase investment for economic growth. The detailed research design is described in *Figure 1*. The methodology of this study is designed to ensure that roads are handled effectively and efficiently. The study involves four stages, each of which is crucial to the success of the project. The first stage involves goal setting. By observing and compiling hypotheses about the existing conditions of road performance, we can identify the causes of any problems and compare them with relevant theories to determine the ideal conditions that should be the objectives of this study. The second stage is problem formulation. By identifying the gap between the existing problems and the objectives that will address the theory, we can compile a detailed plan to tackle the issues at hand. The third stage involves compiling supporting data to complete the analysis that will be carried out for problem-solving. By distinguishing between primary data obtained directly from the field and secondary data obtained from reliable sources, we can ensure that our analysis is accurate and reliable. In the fourth and final stage, we will use the resulting analysis as a conclusion and a reconciliation to be used as a policy and program for handling roads. The success of this study will depend on our ability to follow each of these stages carefully and with precision.

3.2Research variables and parameters

In terms of theoretical studies, an appropriate analytical framework is needed to describe the relationship between economic growth on the one hand and infrastructure development and the impact of disruptions that arise with it [48]. This requires a structured analytical framework and the support of existing technological advances. An understanding of the influencing criteria and sub-criteria is needed.
The research criteria and sub-criteria were determined by a theoretical approach based on study literature, secondary data analysis, and expert interviews. The main concepts of resilience were used to select criteria and sub-criteria related to hinterland connection routes.

Engineering

Important parameters that become indicators are:
- Robustness refers to the ability part of the system, and other analytical measures to withstand certain levels of strain and others' demands without losing function [32, 49]
- Vulnerability. There is a risk of incidents that could make it difficult to use the road network. [50, 51];
- Recovery. Repair, reinforcement, or replacement may be necessary [27, 28].

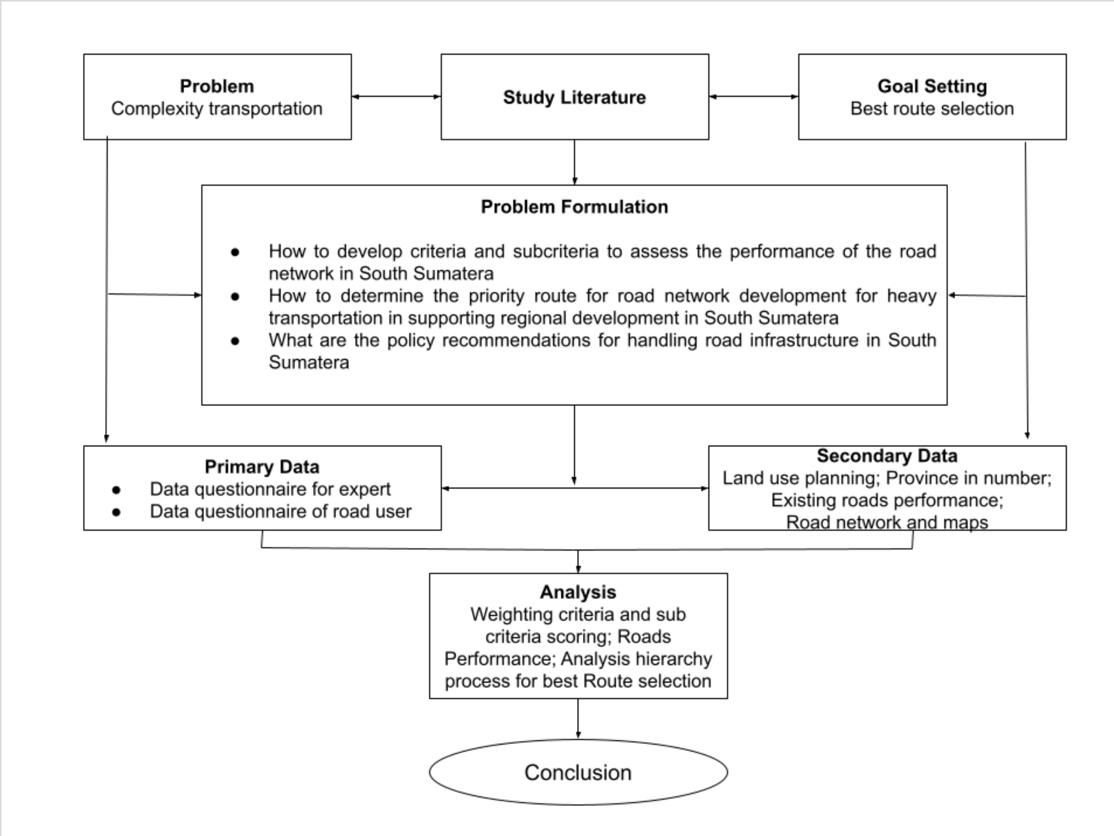

Figure 1 Flow chart research

1) Transportation:

The more detailed variables are:

- Moda alternative. It is a term used to refer to the importance of public transportation in policy-making [52].
- Reliability refers to the probability that a transportation system will sustain a satisfactory level of service following an occurrence. [19, 53, 16];
- Redundancy refers to the diversity of travel options and the amount of spare capacity in the network. The latter can be measured as the amount of reserve capacity still available throughout the network[54];

Social and economic aspects:

In detail, those variables are:

- Cost efficiency: Effective infrastructure can lower logistics expenses, leading to more competitive product prices [55];
- Feasibility study. An economic analysis is necessary to evaluate the efficiency of the project among several options [56];
- Regional potential: There is a relationship between transportation and economic development, which can have an impact on regional growth[57];

Environmental aspects:

The detailed variable is:

- Climate change
- The surrounding environment contributes to the lives of humans, animals, and plants[7];
- Environmental Impact. people activities and resource use can have an impact on decreasing environmental quality [56];
- Nature conservation. Steps must be taken to ensure adequate safety by maintaining natural conditions that can damage construction [58].

3.3Data collection

A sample refers to a subset or unit of measure of a population being observed. To make informed decisions and draw conclusions, it is important to have sufficient information. This means determining the number of respondents or observations required for a study to accurately represent the existing population [59].

The study assessed the importance of road network system factors through expert perception and user feedback. Expert training was carried out to 30 (thirty) respondents representing the interests of road operators, road implementers, researchers, and expert lecturers. They were asked the question, "How much is the level of importance among several selected assessment criteria of this group on the assessment of predetermined criteria, and sub-criteria. Comparative assessment in this case using the Likert scale.

The results of the field questionnaire were weighted with a numerical scale assessment from number 1 stating the lowest and unimportant choice to number 5 stating the very important choice or the main factor. The primary objective of utilizing questionnaires in this research is to gather pertinent information with the utmost reliability and validity. Hence, the precision and consistency of surveys or questionnaires constitute a critical aspect of the research methodology, commonly known as validity and reliability [60].

The next crucial step involves converting raw data into a simpler and understandable format. In this study, we used Google Forms to collect data, ensuring security and facilitating analysis. Once collected, the data is subjected to rigorous tests to verify its validity and reliability. To test the questionnaire's validity, we employ factor validity and item validity tests, which group questionnaire items into interrelated factors and determine how well each item measures the desired variable, respectively. We assess the questionnaire's reliability using the statistical package for social science (SPSS) software, which calculates mean, variance, and standard deviation. These tests ensure that the data we work with is reliable and accurate, allowing us to draw meaningful conclusions from our analysis.

3.4 Data analysis

Data analysis of variable data against each route's performance is conducted using the MCA method. The procedure entails evaluating all facets of criteria and sub-criteria and organizing them in a hierarchical structure. As shown in *Figure 2.*

At level 4, there are four criteria, namely engineering criteria with three sub-criteria, transportation criteria with three sub-criteria, economics criteria with three sub-criteria, and ecological criteria with three sub-criteria. During the assessment process, the weight value of the criteria is determined based on expert opinions, while road performance values are derived from the perspective of road users.

The importance weight of each criterion is obtained through a process of compiling a pairwise comparison matrix of each respondent's results. This data is collected from interview survey results. The average weight for all stakeholders is calculated and Performance scoring undergoes alternation, followed by performance assignment.

The MCA method is employed to evaluate variable data against the performance of each route. A hierarchy is formed by comparing all aspects of criteria and sub-criteria, as depicted in *Figure 2.*

3.5 Analytical hierarchy process (AHP)

The AHP is a popular method used in making decisions. This process involves creating a hierarchy to determine the size and importance of criteria and sub-criteria by comparing them in pairs. Saaty was introduced in 1970 [61, 62].

Utilizing the AHP method aims to attain a goal by incorporating numerous crucial factors through pairwise comparisons among stakeholders participating in the decision-making process. Higher weights signify greater significance assigned to criteria, while lower weights indicate less importance. The ultimate rating is derived by merging the weight of the criteria with the performance level of alternative solutions [63].

The use of AHP method can also be used to test whether an existing policy has been prepared for appropriate consideration and involves various stakeholders. This method can also be used to identify fault points on the road network and anticipate their causes [64]. As shown in *Table 1*

To successfully create a hierarchical structure, it is crucial to begin with setting clear and concise goals, followed by identifying the necessary criteria, sub-criteria, and alternatives at the lowest level. The AHP is chosen over another decision-making process because it is suitable for this study. By breaking down complex problems into simpler hierarchical structures, this method can be applied in various decision-making contexts. This makes it easier to analyze relationships between decision elements [65]. This method allows to give weight to each criterion and alternative, thus allowing decision-makers to quantitatively consider different relevant aspects [61]. The use of AHP method can also be used to test whether an existing policy has been prepared for appropriate consideration and involves various stakeholders [66].

Table 1 Vehicle data per roads section

Route	Private	Passenger	Commercial	Bus	Heavy	Total
Lubuklinggau-Sekayu-Palembang.	5086	7723	6031	6367	41476	66683
Lampung - OKU - Palembang.	15642	23763	18540	13433	36895	108273
Lubuklinggau- Lahat-Palembang.	14051	21305	16652	12183	65315	129506
Palembang – Betung - Jambi	6587	9993	7797	10276	61987	96640
Lampung- KayuAgung-Palembang	11258	17096	13342	14199	79456	135351

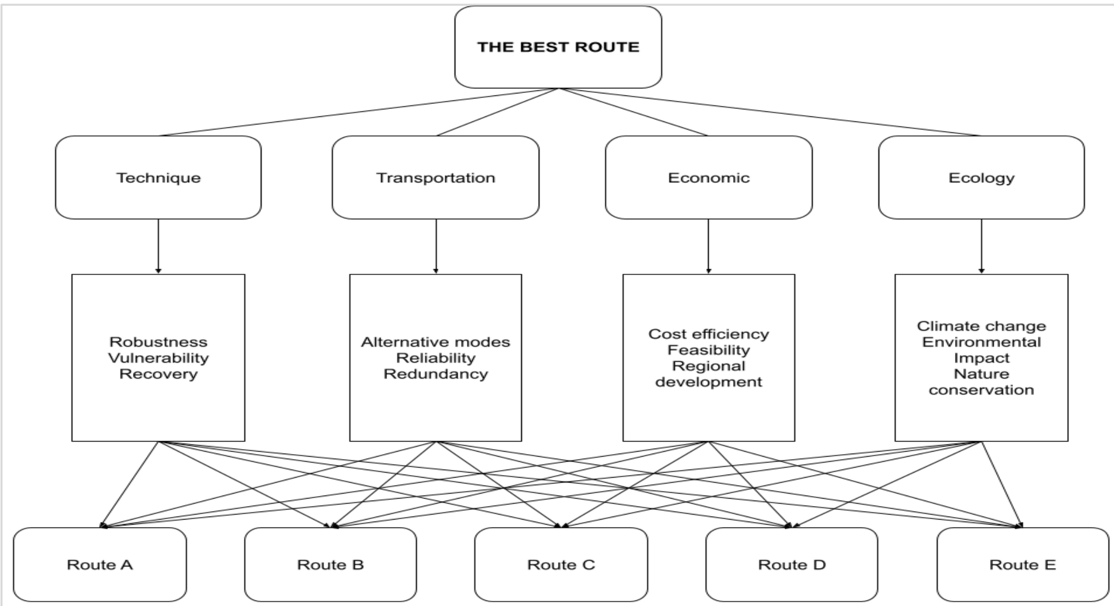

Figure 2 Compilation of level hierarchies

3.6 Population

The population used in this study refers to the average daily traffic data on each road section, the data used is secondary data obtained from the central national road office of South Sumatra province. The data obtained are grouped on the type of vehicle and then the highest average daily traffic is used as a basis for determining the sample, the sample size is determined using the Slovin method.

3.7 Sampling method

A study was conducted in South Sumatra, Indonesia to gather perceptions of road performance from 400 prospective respondents aged 15-60 years. Interviews were conducted, and data was collected from secondary sources and road officials. Slovin's method was used to determine the sample size, and the study aimed to provide insights to improve road performance and ensure the safety of all road users. The number of samples was calculated based on Slovin's theory with a confidence level of 95%.

The Slovin Equation 1 is as follows:

$$n = N/(1+(N\times e^2)) \quad (1)$$

$$n=68079/(1+(68079\times 0.05^2)) = 398$$

Where: n = number of samples

N=Average daily traffic maximum.

e=percent limit error (5%).

Consequently, the number of samples calculated for this study amounted to 400. Furthermore, these 400 samples have been utilized to represent the population of road users.

3.8 Respondent profile

Two types of questionnaires were used in the study. The first was addressed to the expert group, and the second was addressed to road users. The expert respondents were selected based on their expertise and were asked about their perceptions of the weighting criteria. On the other hand, road users were asked about their experiences with road performance while driving. The respondent information was used to compile frequency data and create a profile of the selected respondents for the study. As shown in *Table 2*. The study also used numerical scale assessments to weigh the results of the field questionnaires as shown in *Table 3*. The scores obtained were normalized and converted into a performance score assessment scale, which was used to evaluate all selected road routes.

Table 2 Profile of respondent assessment parameter

Respondent	Roads User	Roads Official	Expert
Private Transport	40	-	-
Passenger transport	57		
Commercial transport	45		
Bus Transport	43		
Heavy Freight	215		
Road's official Of National Roads, Provinces, and Districts	-	12	-
Contractor, consultant	-	12	-
Lecturer	-	-	6

Table 3 Road performance assessment scale

Significance level	Definition	Notes
1	Not important	The parameters do not influence the performance of the existing road.
2	Quite important	The parameter significantly affects the performance of the existing road network.
3	Important	The parameters play a crucial role in the performance of the existing road network.
4	Very important	The parameters have a more substantial influence on the performance of the existing road network.
5	Extremely important	The parameters have proven to be a pivotal factor with a significant impact on the performance of the existing road network.

For the use in evaluating the street prioritization model, survey results are weighted with a numerical scale rating from 1, which indicates the least important choice, to 5, which indicates the most important choice or dominant factor.

4.Result

4.1Weighting criteria

The weighting process to obtain the importance weight of each criterion is generally carried out with the following methodology:

- Test normality and correlation with multilinear regression.
- Compile a pairwise comparison matrix of each respondent's results to obtain the weight of the criteria.
- Calculates the Eigenvalue, consistency index (CI) (Equation 2), and consistency ratio (CR) (Equation 3).
- Calculate the average weight for all stakeholders.
- Alternate performance scoring.
- Performance assignment.

The questionnaire data was analyzed by experts using code numbers ranging from 1 to 5. An initial matrix was compiled from these tabulations, which was then converted into a comparison normalization matrix in pairs. This matrix process was applied to all criteria and sub-criteria. The pairwise comparison matrix results helped to determine the CI and CR through sensitivity tests. If the CR is less than 0.1, the respondents' answers are considered consistent. However, if the CR is greater than 0.01, the data is considered inconsistent and must be repeated As shown in *Table 4.*

Table 4 Paired wised matrix between technique criteria

	A1	A2	A3	Total		A1	A2	A3	Total	Eigen Value	Z	K Vector
A1	1	3.1063	2.3146	6.421	A1	0.5701	0.6392	0.4986	1.7079	0.5693	1.7443	3.063
A2	0.321	1	1.3273	2.649	A2	0.1835	0.2057	0.2859	0.6752	0.2250	0.681	3.026
A3	0.432	0.7533	1	2.185	A3	0.2463	0.1550	0.2154	0.6167	0.205	0.6211	3.021
	1.753	4.8597	4.642	1.2556		1	1	1	3	1	3.0467	9.111

Sensitivity analysis from the above table is:
Eigen max = 9.118/3 =3.037
Consistency index (CI) = (λ max – n)/(n–1) (2)
= (3.037- 3)/(3-1) = 0.0186
Consistency ratio (CR) = CI/ Random Index (3)
CR = (0.0186)/ (0.58) = 0.032.
Random Index Saaty for n = 3 is 0.58.

The CR value obtained is 0.032, and the CR value is < 0.1; then the answers given by respondents are declared consistent. The calculations described are performed for all other criteria and sub-criteria. The result of compilation a paired comparison matrix is shown in *Table 5*.

Table 5 Weighting the criteria and the sub criteria

No.	Criteria	Weighting criteria	No.	Criteria	Weighting criteria
	Technique	0.3773	C	Economy.	0.32805244
A	Robustness.	0.5693		Feasibility.	0.445659459
	Vulnerability	0.22508		Cost efficiency.	0.226288101
	Recovery	0.20559		Regional Potential	0.2116
B	Transportation	0.2989	D	Ecology.	0,1186
	Alternative modes.	0.51634		Climate change.	0.261277145
	Travel time.	0.312		Environmental impact.	0.481531022
	Connectivity	0.312		Natural conservation	0.257191833
	Capacity	0.312			
	Redundancy.	0.17167			

4.2Alternative performance scoring

This study assessed road performance through direct interviews with transport drivers to obtain firsthand perceptions of road users. Each sub-criterion had one question to answer. The road performance assessment process is carried out on each route, The evaluation is conducted using a scale ranging from 1 to 5. A rating of 5 signifies the utmost significance, while a rating of 1 indicates the lowest level of importance, denoting significance. Further details can be found in *Table 6*.

Table 6 Alternative route performance calculations

	Technique			Transportation					Economy			Ecology		
Route	**A1**	**A2**	**A3**	**B1**	**B21**	**B22**	**B23**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**
A	3.076	2.458	3.161	2.752	2.330	2.815	2.267	3.071	2.552	2.611	2.449	2.001	3.991	3.299
B	3.874	3.672	3.693	3.475	3.746	3.606	3.062	3.648	3.243	3.187	2.970	2.592	4.477	3.515
C	4.108	3.891	3.973	2.729	3.720	4.056	3.033	3.072	3.096	3.369	2.856	2.371	3.594	3.934
D	2.986	1.708	2.619	2.006	2.001	2.697	1.989	2.085	2.014	1.759	1.624	1.510	4.923	3.557
E	3.952	3.347	3.593	2.468	3.661	4.011	2.711	2.335	3.251	2.985	2.937	2.528	3.353	3.637
Avg	2.984	2.524	2.776	2.136	2.625	2.874	2.159	2.228	2.321	2.260	2.078	1.800	3.269	2.928

4.3Performance assignment

This study determined the best route for the hinterland connection of South Sumatra province by calculating the final score of each alternative road route. The score was obtained by multiplying the weight factors of the criteria with the road performance score. For example, the technical criteria performance of the Lubuklinggau - Sekayu - Palembang route is calculated using *Tables 5* and *6*. The weight of the technical criteria is robustness, vulnerability, and recovery. The performance score for robustness is 3.076, vulnerability is 2.458, and recovery is 3.161. Then the performance value of the route choice becomes:
P = (3.076×0.56933)+(2.458×0.22508) +(3.161×0.20559)=2.8428.

Referring to the road performance assessment scale as explained in *Table 3*, the assessment scale uses a scale of 1 to 5, the road performance for the engineering criteria on the Lubuklinggau - Sekayu - Palembang route is classified as Important Priority. Further calculations for other routes are shown in *Table 7*.

Table 7 Final calculation of route selection

No.	Alternative Route	Technique	Transportation	Economy	Ecology	Total	Avg.
1	Lubuklinggau-Sekayu-Palembang	2.8248	3.5541	2.5552	3.2936	12.227	3.0569
2	Lampung-Oku-Palembang	3.7912	4.7144	3.1563	3.7369	15.398	3.8497
3	Lubuklinggau-Lahat-Palembang	4.0314	4.3621	3.1635	3.3619	14.919	3.7297
4	Palembang -Betung- Jambi.	2.6227	2.8593	1.8119	3.6799	10.974	2.7435
5	Lampung- Kayu Agung-Palembang	3.7419	4.0689	3.0612	3.2101	14.082	3.5205
Average		3.3102	3.7696	2.6474	3.3247		

5. Discussion

The development of transportation has a strong correlation with the characteristics of land use and socioeconomics. The transportation criteria received the highest score of 3.769652 on a 5 scale, which means that among the stated criteria, transportation problems are still the most important in assessing the performance of the road network Maryono [67] stated that Travel demand varies by activity type, which is linked to land use. Estimating travel demand helps plan transportation systems and policies. The relationship between transportation and land use can be used to evaluate the supply and demand of transport networks. Tamin [8] conducted research on transport infrastructure in West Java based on seven criteria. The results showed that some districts met the highest standards of accommodation for travel needs, followed by street hierarchy integration, accessibility and connectivity, and reliable areas. The sub-criteria for considering travel needs were road transport capacity, optimal operating speed, and good system reliability.

Alternative modes have the highest impact during disruptions, with a weight of 51.63% or 0.51634. To ensure direct and safe transportation of goods and services, especially heavy transportation, prioritize the sub-criteria for alternative modes. Alternative modes cannot be overlooked for a robust transportation system.

The next focus of attention is the technical aspect criteria, especially the robustness sub-criteria. From this study, the weighted value for robustness is quite high, namely 0.56933 or 56.93% compared to 0.225084873 for vulnerability and 0.205589553 for recovery.

In terms of road network performance, several important analyses are drawn for the development of road network content in South Sumatra province.

The reliability capacity performance assessment yielded the highest score for the Lubuklinggau-Lahat–Palembang route, which achieved an importance level score of 4.05563, categorized as extremely high. Closely following was the Palembang–Kayu Agung–Lampung route with a score of 4.0105. These results indicate that these routes continue to be vital arteries for supply chain transportation, remaining the preferred options for heavy transportation with large capacities.

The development of strategic networks in the hinterland connection of South Sumatra can be grouped into four development areas, including:

Route Lubuklinggau-Sekayu-Palembang

Analysis of the above data, the level of significance gets the lowest average value, which is smaller than the three other routes. The lowest value on technical and economic criteria means that currently, the route has not become the main choice for the transportation of goods and services while the stability of the road is not good. Therefore, it is considered unable to support the economic needs of the community.

Lubuklinggau-Lahat-Palembang-Oku-Lampung

As a result of the analysis, the Lampung-Oku-Palembang route received the highest performance rating of 3.849728 from the overall criteria calculated for the entire existing route, followed by the Lubuklingau-Lahat-Palembang route with 3.729773. These results may be acceptable since this route is the main route that connects South Sumatra province to Lampung and Java.

The Palembang-Betung-Jambi route

This route serves as a road connection between South Sumatra and Jambi provinces. However, according to the scoring, it currently faces numerous challenges, particularly in the technical aspects of road safety and economic factors, receiving a score of only 2.7435. With improvements in road infrastructure, this route has the potential to become a critical component of an alternative or redundant pathway in the expanding supply chain between Jambi and South Sumatra provinces.

Route Lampung-Kayu Agung Palembang

This route, serving as the principal conduit to Java Island, received a total score of 3.5205, indicating a good level of performance. Given this score, it holds significant potential for development as a redundant route. Enhancing this route could substantially increase connectivity and transportation capacity, thereby supporting the economic link between South Sumatra and Java.

At the strategic level, the main results of this research are developed as a basis for technical considerations in decision-making. Understanding resilience indicators provides crucial insights for decision-making. Decision-makers can evaluate the impact of proposed transport schemes and road network performance during disruptions. By developing techniques to measure resilience, it is possible to create software to optimize the road network's performance during unexpected events.

The environmental and social implication of this paper's finding is by including ecological aspects as sub-criteria in MCA, transportation problems due to natural conditions in South Sumatra province can be considered properly. On the other hand, including the social aspect we can take into account the aspects of residential along the roads and economic activities such as open markets and parking that use almost half of the road area. Thus, it has taken into account environmental sustainability.

This study's novelty lies in developing a methodology for choosing the optimal route for hinterland connections in South Sumatra province. A summary of the main findings is outlined below:

- This integrated approach provides a more complete understanding of the resilience of different route options and enable more detailed information for decision-making in the future.
- The implementation of the resilient concept in the road transportation system in disruptive conditions can be used as a database to anticipate the level of disruption that can reduce road reliability. This approach can account for changing climate patterns, emerging risks, and future uncertainties, enabling the selection of routes that are adaptable and resilient in the face of evolving conditions.
- The GRMS approach is used for strengthening analysis by further developing technical aspects to optimize the road's system and placing the road's system as part of land use planning.
- Provides a holistic view of the system and helps to identify potential weaknesses and promote potential economic growth for investment. This approach can be applied to other ports and hinterland connection transportation networks to enhance their resilience.

This research employs MCA to assess the performance of transportation networks based on various criteria and sub-criteria. This approach allows researchers to consider various relevant factors in decision-making related to transportation infrastructure.

One advantage of this method is its ability to take into account many aspects of decision-making. By enabling assessments based on different criteria, MCA provides researchers with a more holistic understanding of transportation network performance.

Additionally, MCA facilitates open and structured decision-making. By organizing criteria and sub-criteria hierarchically and involving stakeholders in the pairwise comparison process, this method helps reduce subjectivity and enhance transparency in the decision-making process.

However, this research also has some limitations. The complexity of MCA analysis requires adequate data support. The limitation of this research is the scope of research data. It is limited to the National Road Class of South Sumatra Province. So, it restricts the generalization of criteria selection and findings. Different geographical conditions may require deeper investigation and adjustment to existing characteristics.

Furthermore, MCA results can be influenced by assumptions made in the analysis process and subjectivity in assessing criteria and sub-criteria. Therefore, it is crucial to validate results and consider uncertainty in interpreting findings. Proper selection of information sources according to the criteria needs significantly determines the accuracy of the generated analysis.

The MCA method offers a robust approach to evaluating transportation network performance. However, understanding both its advantages and limitations is essential for effectively utilizing research results in transportation infrastructure decision-making.

A complete list of abbreviations is summarized in *Appendix I.*

6. Conclusion and future work

The MCA conducted in this paper has yielded significant insights, particularly in the evaluation of weighting criteria, road performance, and optimal route selection. The obtained results indicate that technical criteria carry the highest weight, standing at 0.37373, followed by transportation at 0.2989, and economics at 0.32805, with ecology registering the lowest weight at 0.1186. In a more detailed examination of the technical sub-criteria, robustness is assigned a weight of 0.5693, vulnerability 0.22508, and recovery 0.20559. Sub-criteria related to transportation contribute to the overall assessment, with alternative modes assigned a weight of 0.51634, reliability at 0.312, and redundancy at 0.17167.

Economic considerations are also factored in through sub-criteria, where feasibility is weighted at 0.4456, cost efficiency at 0.2262, and regional potential at 0.2116. Lastly, ecological aspects are incorporated into the analysis, with climate change assigned a weight of 0.2612, environmental impact at 0.4815, and natural conservation at 0.2572.

These findings provide a comprehensive overview of the criteria influencing road performance and route selection. The emphasis on technical aspects, alongside considerations of transportation, economics, and ecology, underscores the multi-faceted nature of decision-making in this context. This structured approach can serve as a valuable guide for decision-makers involved in road planning and route optimization, ensuring a well-informed and balanced decision-making process.

The Lampung-Oku-Palembang route has secured the top spot, boasting the highest overall performance score of 3.849728, while the Lubuklinggau-Lahat-Palembang route closely follows with a commendable score of 3.729773. These outcomes underscore the efficiency and effectiveness of these routes in various evaluation aspects.

Consequently, it is imperative to prioritize heightened investment in road infrastructure, with a specific emphasis on the expansion of the Palembang Port into an International Port. This strategic investment holds significant importance in supporting the economic development of the South Sumatra province. By concentrating efforts on upgrading road infrastructure and elevating port facilities to international standards, the region stands to gain substantially in terms of enhanced connectivity, streamlined trade processes, and overall economic growth.

The notable performance scores of these routes emphasize their pivotal role in the transportation network, indicate the necessity for targeted investments to capitalize on their potential. Initiatives aimed at developing and modernizing infrastructure not only improve regional connectivity but also make substantial contributions to the broader economic advancement of the South Sumatra province.

The result of this research develops criteria and sub-criteria by using MCA based on transportation problems, road pavement, and spatial planning of South Sumatra province, Indonesia as a commonly developing country. This variable can vary among the countries, further research in other countries such as Europe and America might obtain different criteria and sub-criteria. Research is open for further development of GRMS. Further development is recommended by creating a framework for PMS and RMS database application.

Acknowledgment
The author extends appreciation and gratitude to the Civil Engineering Department of the University of Sriwijaya, Palembang, and the survey team, for their invaluable help and support throughout the research work.

Conflicts of interest
The authors have no conflicts of interest to declare.

Data availability
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author's contribution statement
Nobel Nawawi: Contribution of data preparation, research modeling analysis, and setting of performance assignment research**. Erika Buchari:** Supervision, Investigation on challenges and Draft manuscript preparation. **Joni Arliansyah:** Field data survey, Writing – review and editing. **Decky Oktavian Syah:** Contributed to the field data collection survey and secondary data.

References
[1] https://sumsel.bps.go.id/publication/2022/02/25/f9646f2d59150d7c3e1201c2/provinsi-sumatera-selatan-dalam-angka-2022.html. Accessed 02 February 2024.

[2] Hudson WR, Haas R, Uddin W. Infrastructure management: Integrating design, construction, maintenance, rehabilitation, and renovation. McGraw-Hill, New York; 1997.

[3] Buchari E. The importance of hinterland connection to improve port productivity in south Sumatera. Eastern Asia Society for Transportation Studies. 2015.

[4] https://balai3.files.wordpress.com/2018/10/renstra1.pdf. Accessed 02 February 2024.

[5] Indrayani I, Asfiati S. Pencemaran udara akibat kinerja lalu-lintas kendaraan bermotor di kota medan. Jurnal Permukiman. 2018; 13(1):13-20.

[6] Muneera CP, Karuppanagounder K. Econommic impact of traffic congestion-estimation and challenges. 2020; 68(5):1-19.
[7] Indrayani AS. Air Pollution Due to Traffic Performance. Air Pollution Due to Traffic Performance of Motor Vehicles in Medan City. Journal of Settlements [Internet]. 2018; 13(1):13-20.
[8] Tamin OZ. Concept for regional transportation system development in the era of regional autonomy. National seminar on strategies for fulfilling needs and determining priorities for regional infrastructure development, directorate general of regional development, ministry of home affairs-Bapenas, Jakarta 2001.
[9] Karami M, Herianto D, Ofrial SA, Yulianti N. Empirical analysis for measuring travel time reliability on road network. Civil Engineering Dimension. 2021; 23(2):100-7.
[10] Chen H, Cullinane K, Liu N. Developing a model for measuring the resilience of a port-hinterland container transportation network. Transportation Research Part E: Logistics and Transportation Review. 2017; 97:282-301.
[11] Imran M, Cheyne C, Harold H. Measuring transport resilience: a Manawatu-Wanganui region case study. 2014: 1-69.
[12] Indirli M, Borg RP, Formisano A, Martinelli L, Marzo A, Romagnoli F, et al. Building resilience in times of new global challenges: a focus on six main attributes. In Geohazards and disaster risk reduction: multidisciplinary and integrated approaches 2023 (pp. 293-319). Cham: Springer International Publishing.
[13] Zhang Y, Cheng L. The role of transport infrastructure in economic growth: empirical evidence in the UK. Transport Policy. 2023; 133:223-33.
[14] Sakketa TG. Urbanisation and rural development in Sub-Saharan Africa: a review of pathways and impacts. Research in Globalization. 2023:100133.
[15] Holling CS. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. 1973; 4(1):1-23.
[16] Berdica K, Mattsson LG. Vulnerability: a model-based case study of the road network in Stockholm. Critical Infrastructure: Reliability and Vulnerability. 2007: 81-106.
[17] Callo-concha D, Ewert F. Using the concepts of resilience, vulnerability and adaptability for the assessment and analysis of agricultural systems. Change and Adaptation in Socio-Ecological Systems Climate Change, Social Changes, Technological Development. 2014; 1(2014):1-11.
[18] Jenelius E, Mattsson LG. Resilience of transport systems. Encyclopedia of Transportation. 2020: 1-16.
[19] Wang JY. ‘Resilience thinking’in transport planning. Civil Engineering and Environmental Systems. 2015; 32(1-2):180-91.
[20] Rose A, Liao SY. Modeling regional economic resilience to disasters: a computable general equilibrium analysis of water service disruptions. Journal of Regional Science. 2005; 45(1):75-112.
[21] Barnett A, Barraclough RW, Becerra V, Nasuto S. A comparison of methods for calculating the carbon footprint of a product. Environ. Monit. Assess. 2012; 178:135-60.
[22] Woods DD. Resilience engineering: concepts and precepts. CRC Press; 2017.
[23] Soltani-sobh A, Heaslip K, El KJ. Estimation of road network reliability on resiliency: an uncertain based model. International Journal of Disaster Risk Reduction. 2015; 14:536-44.
[24] Murray-tuite PM. A comparison of transportation network resilience under simulated system optimum and user equilibrium conditions. In proceedings of the 2006 winter simulation conference 2006 (pp. 1398-405). IEEE.
[25] Behdani B, Wiegmans B, Roso V, Haralambides H. Port-hinterland transport and logistics: emerging trends and frontier research. Maritime Economics & Logistics. 2020; 22:1-25.
[26] Liu X, Li D, Ma M, Szymanski BK, Stanley HE, Gao J. Network resilience. Physics Reports. 2022; 971:1-8.
[27] Ahmed S, Dey K. Resilience modeling concepts in transportation systems: a comprehensive review based on mode, and modeling techniques. Journal of Infrastructure Preservation and Resilience. 2020; 1:1-20.
[28] Pan X, Dang Y, Wang H, Hong D, Li Y, Deng H. Resilience model and recovery strategy of transportation network based on travel OD-grid analysis. Reliability Engineering & System Safety. 2022; 223:108483.
[29] Wang L, Xue X, Wang Z, Zhang L. A unified assessment approach for urban infrastructure sustainability and resilience. Advances in Civil Engineering. 2018; 2018:1-20.
[30] Du Y, Wang H, Gao Q, Pan N, Zhao C, Liu C. Resilience concepts in integrated urban transport: a comprehensive review on multi-mode framework. Smart and resilient transportation. 2022; 4(2):105-33.
[31] Wang L, Xue X, Zhou X. A new approach for measuring the resilience of transport infrastructure networks. Complexity. 2020; 2020:1-6.
[32] Bruneau M, Reinhorn A. Overview of the resilience concept. In proceedings of the 8th US national conference on earthquake engineering 2006 (pp. 18-22).
[33] Rezvani SM, Falcão MJ, Komljenovic D, De ANM. A systematic literature review on urban resilience enabled with asset and disaster risk management approaches and GIS-based decision support tools. Applied Sciences. 2023; 13(4):1-41.
[34] Iannacone L, Sharma N, Tabandeh A, Gardoni P. Modeling time-varying reliability and resilience of deteriorating infrastructure. Reliability Engineering & System Safety. 2022; 217:108074.
[35] Bak O, Shaw S, Colicchia C, Kumar V. A systematic literature review of supply chain resilience in small–medium enterprises (SMEs): a call for further research. IEEE Transactions on Engineering Management. 2020; 70(1):328-41.

[36] Anwar A, Coviello N, Rouziou M. Weathering a crisis: a multi-level analysis of resilience in young ventures. Entrepreneurship Theory and Practice. 2023; 47(3):864-92.

[37] https://lib.ui.ac.id/file?file=pdf/abstrak/id_abstrak-20308417.pdf. Accessed 02 February 2024.

[38] Tamin OZ. Towards the creation of a sustainable transportation system in big cities in Indonesia. Transportation Journal. 2007; 7(2):87-104.

[39] Hot I, Manic N, Šerifi V. 3N-AHP model, the new multiactor multicritera for the selection of optimal corridors of the line infrastructure facilities. Procedia Technology. 2016; 22:365-72.

[40] Tripathi AK, Agrawal S, Gupta RD. Comparison of GIS-based AHP and fuzzy AHP methods for hospital site selection: a case study for Prayagraj City, India. GeoJournal. 2021:1-22.

[41] Colonna P, Fioretti G, Fonzone A, Sasso S. New approaches in road maintenance planning: the global road management system (GRMS). In 13th proceedings of the Mini-EURO conference and the 9th meeting of the EURO working group on transportation, Bari, Italy 2002 (pp. 752-6).

[42] Colonna P, D’amoja SI, Maizza M, Ranieri V. The quality of service in terms of road serviceability as a fundamental parameter for taking technical, economical and strategic choices that concern road network infrastructures. Proceedings of XXIIP 2003 (pp. 1-19).

[43] Colonna P, Fonzone A. New ways of viewing the relationship between transport and development. Pasquale Colonna, Achille Fonzone. 2003.

[44] Sirvio K, Izzatdust Z, Philogene-mckie R. Implementation of road asset management system in Saint Lucia. In 26th World Road Congress World Road Association (PIARC) 2019.

[45] Hendry M. Multi-application smart cards: technology and applications. Cambridge University Press; 2007.

[46] Colonna P, Fioretti G, Fonzone A, Sasso S. From pavement maintenance to territory enhancement: the Global Road Management System (GRMS). Safe Roads in the XXI. Century, Budapest, Hungary. 2002(pp.1-6).

[47] Wegman F, Berg HY, Cameron I, Thompson C, Siegrist S, Weijermars W. Evidence-based and data-driven road safety management. IATSS Research. 2015; 39(1):19-25.

[48] Du X, Zhang H, Han Y. How does new infrastructure investment affect economic growth quality? Empirical evidence from China. Sustainability. 2022; 14(6):1-30.

[49] Boccaletti S, Latora V, Moreno Y, Chavez M, Hwang DU. Complex networks: structure and dynamics. Physics Reports. 2006; 424(4-5):175-308.

[50] Berdica K. An introduction to road vulnerability: what has been done, is done and should be done. Transport Policy. 2002; 9(2):117-27.

[51] Candelieri A, Galuzzi BG, Giordani I, Archetti F. Vulnerability of public transportation networks against directed attacks and cascading failures. Public Transport. 2019; 11:27-49.

[52] De DOJ, Willumsen LG. Modelling transport. John Wiley & Sons; 2024.

[53] Soltani-sobh A, Heaslip K, Stevanovic A, El KJ, Song Z. Evaluation of transportation network reliability during unexpected events with multiple uncertainties. International Journal of Disaster Risk Reduction. 2016; 17:128-36.

[54] Xu X, Chen A, Jansuwan S, Heaslip K, Yang C. Modeling transportation network redundancy. Transportation Research Procedia. 2015; 9:283-302.

[55] Ministry of Public Works. Infrastructure development planning in the context of strategic area development. Strategy Development Regional Infrastructure Integration Plan, Human Resources Development Agency, Education and Training Center for Roads, Housing, Settlements and Regional Infrastructure Development, Bandung. 2017.

[56] Picardo A, Soltero VM, Peralta E. Life cycle assessment of sustainable road networks: current state and future directions. Buildings. 2023; 13(10):1-22.

[57] Polyzos S, Tsiotas D. The contribution of transport infrastructures to the economic and regional development. Theoretical and Empirical Researches in Urban Management. 2020; 15(1):5-23.

[58] Fankhauser S. Adaptation to climate change. Annual Review of Resource Economics. 2017; 9:209-30.

[59] Memon MA, Ting H, Cheah JH, Thurasamy R, Chuah F, Cham TH. Sample size for survey research: review and recommendations. Journal of Applied Structural Equation Modeling. 2020; 4(2):1-20.

[60] Taherdoost H. Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. International Journal of Academic Research in Management. 2016; 5(3):28-36.

[61] Saaty TL. Decision making with the analytic hierarchy process. International Journal of Services Sciences. 2008; 1(1):83-98.

[62] Saaty TL, Sodenkamp M. The analytic hierarchy and analytic network measurement processes: the measurement of intangibles: decision making under benefits, opportunities, costs and risks. In handbook of multicriteria analysis 2010 (pp. 91-166). Berlin, Heidelberg: Springer Berlin Heidelberg.

[63] Tabucanon MT, Lee HM. Multiple criteria evaluation of transportation system improvement projects: the case of Korea. Journal of Advanced Transportation. 1995; 29(1):127-43.

[64] Moslem S, Saraji MK, Mardani A, Alkharabsheh A, Duleba S, Esztergár-kiss D. A systematic review of analytic hierarchy process applications to solve transportation problems: from 2003 to 2022. IEEE Access. 2023; 11:11973-90.

[65] Aliyev R, Temizkan H, Aliyev R. Fuzzy analytic hierarchy process-based multi-criteria decision making for universities ranking. Symmetry. 2020; 12(8):1-15.

[66] Yang Y, Gu J, Huang S, Wen M, Qin Y. Application of uncertain AHP method in analyzing travel time belief reliability in transportation network. Mathematics. 2022; 10(19):1-20.

[67] Maryono M. Modeling complexity of urban land use and transportation in Semarang city. 5th international conference on indonesian architecture and planning 2021 (pp. 1-6). IOP Publishing.

Nobel Nawawi was born in Palembang on August 19th, 1963. He received his Master's Degree in Transportation from Sriwijaya University, Indonesia, in 2005. He is currently a PhD Candidate in Transportation, at Sriwijaya University, South Sumatra Province, Indonesia. He was the former Head of Public Works and is now Assistant II of Regional Secretary. His research interests include Highways, Bridges, and Transportation Engineering.
Email: Nobelramitan1963@gmail.com

Erika Buchari was born in Palembang on October 30th, 1960. She received her Master's Degree in Highway and Transport from City University, London, UK, in 1990. She got her PhD in Multimodal Transportation from Liege University, Liege, Belgium, in 2008. Since 2011 now She has been a Full Professor at Sriwijaya University, South Sumatra Province, Indonesia. Her research interests are in Highway, Port Management, and Multimodal Transport.
Email: erikabuchari@ft.unsri.ac.id

Joni Arliansyah was born in Palembang on June 15th, 1967. He received his Master's Degree in Transportation from Bandung Institute of Technology (ITB), Indonesia, and Dr. Eng in Transportation from Nagaoka University of Technology, Japan. He is currently a Professor at Sriwijaya University South Sumatra Province, Indonesia. His research interests are in Highway and Transportation Engineering.
Email: joniarliansyah@ftunsri.com

Decky Oktavian Syah was born in Palembang on October 10th, 1984. He received his master’s degree in civil engineering from the University Sriwijaya Palembang, South Sumatra, Indonesia in 2015. Currently, he is a PhD candidate at the Faculty of Engineering, Sriwijaya University. Currently, He is a Civil Servant at the Public Works Department, in Indonesia. His research interests include Highways, Bridges, and Transportation Engineering.
Email: decky.dpubm@gmail.com

Appendix I

S. No.	Abbreviation	Description
1	AHP	Analytical Hierarchy Process
2	CI	Consistency Index
3	CR	Consistency Ratio
4	GRMS	Global Roads Management System
5	IRMS	Integrated Roads Management System
6	MCA	Multi-Criteria Analysis
7	PHCTN	Port Hinterland Container Network
8	PMS	Pavement Management System
9	RAMS	Roads Asset Management System
10	RIF	Resilience Indicators Framework
11	RMS	Roads Management System
12	SPSS	Statistical Package for Social Science