

PRIORITIZING SUSTAINABLE TRANSPORTATION STRATEGIES TO SUPPORT TOURISM IN BALI BASED ON ROAD SAFETY, ENVIRONMENTAL SUSTAINABILITY, AND ACCESSIBILITY CRITERIA

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Abstract. Bali as one of the leading tourism destinations in Indonesia faces various transportation challenges, such as limited accessibility, road safety problems, and increasing environmental impacts due to high tourist mobility. This condition requires the determination of a sustainable transportation strategy that is able to support tourism development effectively. This research aims to determine the priorities of sustainable transportation strategies to support tourism in Bali using the Analytical Hierarchy Process (AHP) method. The data was obtained through the distribution of questionnaires, then analyzed using the Expert Choice software. The assessment was carried out based on three criteria, namely road safety, environmental sustainability, and accessibility, with three alternative strategies including strengthening sustainable public transportation, improving safe and inclusive transportation infrastructure, and implementing smart mobility for sustainable tourism. The results of the analysis showed that accessibility was the criterion with the highest weight of 0.524, followed by road safety of 0.266, and environmental sustainability of 0.211, with a Consistency Ratio (CR) value of 0.01 which indicates a good level of assessment consistency. The global synthesis shows that the implementation of smart mobility for sustainable tourism is a priority strategy with a weight of 0.394, followed by strengthening sustainable public transportation (0.353) and improving safe and inclusive transportation infrastructure (0.253). These findings show that the integration of digital technology, strengthening public transportation, and improving accessibility are the most effective strategies in supporting a safe, environmentally friendly, and sustainable transportation system in Bali.

Keywords: Accessibility; AHP; Environmental Sustainability; Road Safety

1. INTRODUCTION

Transportation is an important component in supporting economic development, community mobility, and the sustainability of the tourism sector. In tourist destination areas, transportation systems not only function as a means of transportation, but also become part of the tourist experience in accessing various tourist attractions safely, comfortably, and efficiently. Bali as an international tourist destination faces increasingly complex transportation challenges due to the increasing number of tourists, the growth of motor vehicles, and limited road network capacity. This condition causes congestion in various tourist corridors, especially in the Denpasar, Badung, Ubud, and Canggu areas, which has an impact on travel time, environmental quality, and the level of safety of road users. In addition, increasing transportation activities also contribute to increasing greenhouse gas emissions and energy consumption in the transportation sector, so that the development of a safe and environmentally friendly transportation system is one of the priorities for sustainable development in Bali (Maulidya & Widyastuti, 2024; Mananda et al., 2025).

The urgency of developing safe, environmentally friendly, and sustainable transportation is increasing in line with global commitments to achieve the Sustainable Development Goals (SDGs), especially Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action). According to the Intergovernmental Panel on Climate Change (IPCC), the transportation sector accounts for about 23% of global CO₂ emissions coming from energy activities, with land

transportation accounting for more than 71% of transportation sector emissions. This condition shows that the transformation towards a low-carbon and sustainable transportation system is one of the priority agendas in global climate change mitigation (UNECE, 2023). In Indonesia, road transportation is still dominated by private vehicles, contributing to high energy consumption, congestion, and traffic accidents. On the other hand, Bali receives millions of tourists every year so the need for a safe and sustainable transportation system is even more urgent. BPS statistics show that the number of foreign tourists coming directly to Bali will increase again in 2024 after the recovery of the tourism sector, which directly increases the need for mobility to tourist areas. This condition requires a transportation policy that is able to balance aspects of road safety, environmental protection, and ease of tourist mobility so that the sustainability of destinations is maintained (BPS Bali Province, 2025; Hadidjah & Budiharsono, 2025).

Based on the review of policy documents, government reports, and various scientific publications, there are three main issues that need to be addressed in the development of transportation in Bali. First, from the aspect of road safety, traffic accidents are still a serious problem both globally and nationally. The World Health Organization (WHO) reports that around 1.19 million people die each year due to traffic accidents, with more than 50% of victims being pedestrians, cyclists, and motorcyclists who are classified as high-risk road users (WHO, 2023). In Indonesia, data from the National Police Corps shows that traffic accidents are still dominated by two-wheeled vehicles with a relatively high fatality rate. In the context of Bali, several tourist corridors and national roads show a significant level of accident risk due to high traffic volumes, tourist activities, and limited safety facilities for pedestrians and cyclists (Maulidya & Widyastuti, 2024; Mardikawati et al., 2025). Second, from the aspect of environmental sustainability, the transportation sector is one of the main contributors to greenhouse gas emissions. According to the International Energy Agency (IEA), the transportation sector accounts for nearly 24% of global energy-related CO₂ emissions, with road transportation as the largest contributor (IEA, 2024). In Indonesia, the increase in the number of motor vehicles reaching more than 160 million units in 2023 will also increase energy consumption and carbon emissions in urban areas and tourist destinations (BPS, 2024). Third, from the aspect of tourism mobility, the growth in the number of tourists reaching more than 6.3 million foreign tourists in Bali in 2024 increases the pressure on the transportation system and accessibility of tourist destinations (BPS Bali, 2025). Congestion that occurs in major tourist corridors such as Denpasar-Kuta-Canggu and Ubud not only reduces travel efficiency, but also reduces the quality of the tourist experience and increases the environmental impact due to longer travel times (Mananda et al., 2025). These problems show that transportation development in Bali requires an approach that is not only oriented towards increasing infrastructure capacity, but also considers the balance between road safety, environmental sustainability, accessibility and tourism mobility as the basis for the preparation of effective and sustainable transportation strategies (Hadidjah & Budiharsono, 2025; Mananda et al., 2025).

Studies on road safety, environmental sustainability, and accessibility are generally still being carried out partially, so they have not yet produced a strategic priority that considers these three aspects simultaneously, especially in Bali. To fill these gaps, this article uses the Analytical Hierarchy Process (AHP) to determine the priorities of strategies for integrating road safety, environmental sustainability, and accessibility in supporting sustainable tourism. The findings are expected to provide input for policymakers in designing a safer, more environmentally friendly, and sustainable transportation system.

2. LITERATURE REVIEW

2.1 Road Safety

Road safety is one of the key elements of a sustainable transportation system that aims to reduce the risk of accidents and minimize fatality rates through a human-centered approach to the road environment. In the *Safe System* concept, road safety is not only influenced by the

behavior of road users, but also by the quality of infrastructure, vehicles, and traffic management systems that are integrated with each other. Therefore, improving road safety is one of the priorities in the development of transportation systems that support safe and sustainable mobility (*International Transport Forum, 2022*).

Various studies show that the success of road safety programs is greatly influenced by the level of protection for road users and the quality of available infrastructure. An analysis of urban transport systems shows that groups of road users who do not have physical protection, such as pedestrians and cyclists, have a higher risk of injury and fatality than users of covered vehicles. Therefore, the safety aspect of road users needs to be a key consideration in the transportation planning process and infrastructure investment decision-making (*Chang et al., 2022*).

In addition to the road user factor, road safety infrastructure also has a significant role in reducing the risk of accidents. The provision of adequate sidewalks, safe crossing facilities, bicycle lanes, vehicle speed control, and appropriate road design has been proven to be able to improve the safety and comfort of road users. Case studies conducted in several European countries show that the combination of improved safety infrastructure and vehicle technology has the potential to prevent up to 93% of pedestrian deaths in locations with high accident rates (*Stigson et al., 2023*).

Similar findings also showed that the presence of pedestrian and cyclist facilities had a significant relationship with a decrease in fatal accident rates. Areas with adequate sidewalks, bicycle paths, and crossing facilities tend to have a better level of safety than areas that are still oriented towards motor vehicles. Infrastructure that supports active mobility also contributes to improved environmental quality and reduced reliance on private vehicles (*Zhou et al., 2023*).

Based on the synthesis of these various studies, the road safety aspect in this study is represented through two subcriteria, namely road user safety and road safety infrastructure. The road user safety sub-criteria were chosen because they reflect the level of protection for all transportation users, including tourists, local communities, pedestrians, and cyclists. Meanwhile, the sub-criteria of road safety infrastructure were chosen because the quality of road physical facilities has been proven to have an effect on reducing the risk of accidents and improving mobility comfort. The selection of these two sub-criteria is also relevant to the condition of Bali as an international tourist destination that has high mobility and intensive interaction between vehicles, pedestrians, and cyclists in the main tourist corridors. Therefore, improving the safety of road users and providing adequate safety infrastructure are important factors in supporting a safe, environmentally friendly, and sustainable transportation system in Bali (*Chang et al., 2022; Zhou et al., 2023; Maulidya & Widyastuti, 2024*).

2.2 Environmental Sustainability

Green transportation is a transportation approach that aims to reduce environmental impact through the use of low-emission modes of transportation, increased energy efficiency, and reduced dependence on fossil fuel vehicles. The transportation sector is known to be one of the major contributors to the world's greenhouse gas emissions, with road transportation accounting for the largest proportion of emissions from the transportation sector (*IEA, 2024*). Various studies show that the development of electric vehicles, sustainable public transportation, and active transportation such as walking and cycling are effective strategies to reduce carbon emissions while improving the quality of the urban environment (*Creutzig et al., 2020; Zhang et al., 2023*). In Indonesia, the increasing number of motor vehicles that continues to increase every year has implications for increasing energy consumption and emissions in the transportation sector, so that the transformation towards a low-carbon transportation system is one of the important agendas in supporting sustainable development (*BPS, 2024; Kurniawan et al., 2022*).

As an international tourist destination, Bali faces the challenge of increasing tourist mobility which demands the development of a more environmentally friendly and sustainable

transportation system. The high use of private vehicles in tourist areas has the potential to increase carbon emissions, congestion, and reduce the environmental quality of tourist destinations (Mananda et al., 2025).

2.3 Accessibility

Accessibility is one of the key factors in the development of sustainable transportation and tourism because it reflects the ease of tourists in reaching destinations through efficient, connected, and accessible transportation systems. Various studies show that increasing accessibility through intermodal integration and the provision of adequate transportation services contributes to increasing the competitiveness of tourist destinations while supporting sustainable mobility (Bergantino et al., 2023). In Indonesia, transportation accessibility is also a factor that affects tourist satisfaction and the success of tourist destination development, especially in areas with high mobility (Birahmatika et al., 2025). A similar condition occurs in Bali, where limited public transportation connectivity to tourist destinations is still one of the main obstacles, so it is necessary to increase accessibility through a more integrated and sustainable transportation system (Aryasih et al., 2024; Raharjo et al., 2023). Therefore, accessibility was chosen as one of the criteria in this study because it has an important role in determining transportation strategies that are able to improve safety, environmental sustainability, and the quality of tourism mobility in Bali.

3. RESEARCH METHODS

3.1 Research Approach

This study uses a quantitative approach with a *Multi-Criteria Decision Making (MCDM)* method through the Analytical Hierarchy Process (AHP) technique. The quantitative approach was chosen because this study aims to determine the priorities of safe, environmentally friendly, and sustainable transportation development strategies based on experts' assessments of a number of criteria, and alternatives that have been determined. The AHP method allows complex decision-making processes to be carried out systematically through *pairwise comparison*, so that priority weight can be generated at each level of the hierarchy. The research data was obtained through questionnaires given to stakeholders who have competence in the fields of transportation, road safety, environment, and tourism. The results of the analysis were used to identify the most influential factors and determine alternative strategies that are priorities in supporting the development of a safe, environmentally friendly, accessible and sustainable transportation system in Bali.

3.2 Location and Research Object

This research was carried out in Bali Province as one of the main international tourist destinations in Indonesia that faces challenges in developing a safe, environmentally friendly, and sustainable transportation system. The object of the research is a transportation development strategy that supports road safety, environmental sustainability, and accessibility. The analysis is focused on determining strategic priorities based on the assessment of experts and stakeholders from government agencies, academics, transportation practitioners, and the tourism sector. This study evaluates three main criteria, namely road safety, environmental sustainability, and accessibility, along with relevant alternative strategies to support the development of sustainable tourism in Bali.

3.3 Population and Sample

The population in this study is all stakeholders who have knowledge, experience, and involvement in the planning, management, and development of transportation and tourism systems in Bali Province. The population includes elements of the government, academics, transportation practitioners, tourism industry players, and organizations related to road safety

and environmental sustainability. The sampling technique used is purposive sampling, which is the deliberate selection of respondents based on competence and experience relevant to the research objectives. This method was chosen because the research uses the Analytical Hierarchy Process (AHP) which requires expert judgment in conducting paired comparisons of criteria, and alternative strategies.

3.4 Data Collection Techniques

Data collection in this study was carried out through literature studies, document reviews, and the dissemination of questionnaires to experts (expert judgment). A literature study was conducted to identify concepts, criteria, and alternative strategies related to road safety, environmental sustainability, and accessibility. The literature used comes from articles from reputable international journals, proceedings, reports of international organizations, as well as policy documents related to sustainable transportation and tourism.

3.5 Data Analysis Techniques

The data was analyzed using the Analytical Hierarchy Process (AHP) method. The first stage is to compile a hierarchical structure consisting of goals, criteria, and alternative strategies. The second stage is to conduct a *pairwise comparison* using the fundamental scale of Saaty 1–9 based on the assessment of experts. Furthermore, consistency testing was carried out to ensure that respondents' assessments were logical and consistent through the Consistency Ratio (CR) value, with a CR acceptance limit of ≤ 0.10 . The final stage is to determine the strategy priorities based on the results of data processing using the Expert Choice 11 software, so that the most effective alternatives are obtained in supporting the development of a sustainable transportation system in Bali.

4. RESULTS AND DISCUSSION

4.1 Priority Criteria

Priority analysis of criteria was carried out using the Analytical Hierarchy Process (AHP) method with the help of Expert Choice software. The results of the analysis showed that all expert assessments met the consistency requirements with a Consistency Ratio (CR) value of 0.01, which means that it is smaller than the limit recommended by Saaty (1980), which is $CR \leq 0.10$. Thus, the weighting results can be declared consistent and feasible to be used as a basis for determining strategy priorities. Based on the results of the analysis, accessibility was the criterion with the highest weight of 0.524 (52.4%), followed by road safety of 0.266 (26.6%), and environmental sustainability of 0.211 (21.1%) as shown in Figure 1.

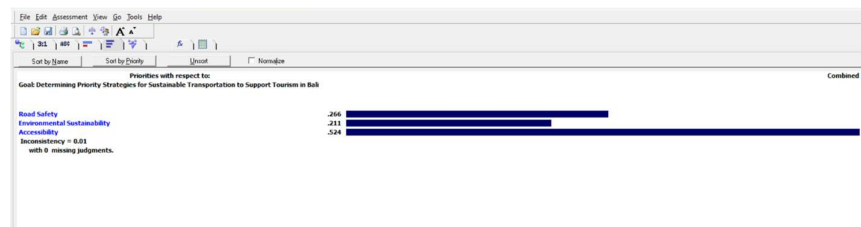


Figure 1. Prioritizing Criteria

These results show that improving accessibility is the most prioritized aspect in the preparation of sustainable transportation strategies in Bali. This shows that the ease of tourists and the public in reaching tourist destinations is still the main challenge of the transportation system in Bali. This condition is in line with various studies that state that connectivity between destinations, integration of transportation modes, and ease of access are important factors in increasing the competitiveness of tourist destinations. Meanwhile, road safety is the second priority because the high traffic activity in tourist areas requires a transportation system that is

able to provide a sense of security for all road users. Environmental sustainability remains an important aspect, but it is considered not to be a top priority compared to the need to improve accessibility and safety.

4.2 Alternative Priorities on Each Criterion

The results of the analysis show that each criterion results in a different alternative strategy as the top priority. In the road safety criteria, the alternative of Improving Safe and Inclusive Transportation Infrastructure (A2) obtained the highest weight of 0.459, followed by the Implementation of Smart Mobility for Sustainable Tourism (A3) of 0.310, and Strengthening Sustainable Public Transportation (A1) of 0.231 as shown in Figure 2.



Figure 2. Alternative Priorities on Road Safety Criteria

These results indicate that improving the quality of infrastructure such as sidewalks, bicycle lanes, crossing facilities, traffic signs, and other safety facilities is seen as the most effective strategy in improving the safety of road users. Adequate infrastructure is believed to be able to reduce the risk of accidents while increasing the comfort of tourists and local communities.

In the environmental sustainability criteria, the alternative of Strengthening Sustainable Public Transportation (A1) became the first priority with a weight of 0.412, followed very closely by the Implementation of Smart Mobility (A3) of 0.404, while Transportation Infrastructure Improvement (A2) received a weight of 0.184 as shown in Figure 3.



Figure 3. Alternative Priorities on Environmental Sustainability Criteria

These results show that the development of public transportation is considered the most effective strategy in reducing the use of private vehicles so that it can reduce carbon emissions and energy consumption. In addition, the implementation of smart mobility systems is also seen as able to support travel efficiency through route optimization and digital traffic management.

Meanwhile, in the accessibility criteria, the alternative Smart Mobility Implementation for Sustainable Tourism (A3) obtained the highest weight of 0.433, followed by Strengthening Sustainable Public Transportation (A1) by 0.391, and Improving Safe and Inclusive Transportation Infrastructure (A2) by 0.176 as shown in Figure 4.

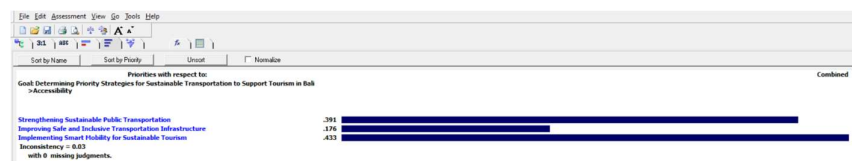


Figure 4. Alternative Priorities on Accessibility Criteria

This shows that the use of digital technology, such as real-time travel information systems, integrated transportation applications, and electronic ticket systems, is considered to be able to increase the ease of tourists in accessing various tourist destinations more efficiently.

Overall, the results of this study show a difference from most previous studies that generally focused on only one aspect, such as road safety, green transportation, or accessibility separately. This study integrates these three aspects in a single decision-making framework using the Analytical Hierarchy Process (AHP) method so that it is able to produce a more comprehensive strategic priority. Thus, this research not only provides a theoretical contribution in the form of a multi-criteria evaluation model, but also offers practical recommendations for local governments in determining sustainable transportation policies that support tourism development in Bali.

4.3 Performance Sensitivity Analysis

Figure 5 below shows the results of the performance sensitivity analysis which illustrates the relationship between the weight of each criterion and the performance of each alternative strategy. The results of the analysis showed that accessibility was the criterion that had the highest weight of 52.4%, followed by road safety at 26.6%, and environmental sustainability at 21.1%. This condition indicates that experts consider increased accessibility to be the most decisive aspect in the formulation of sustainable transportation strategies to support tourism in Bali.

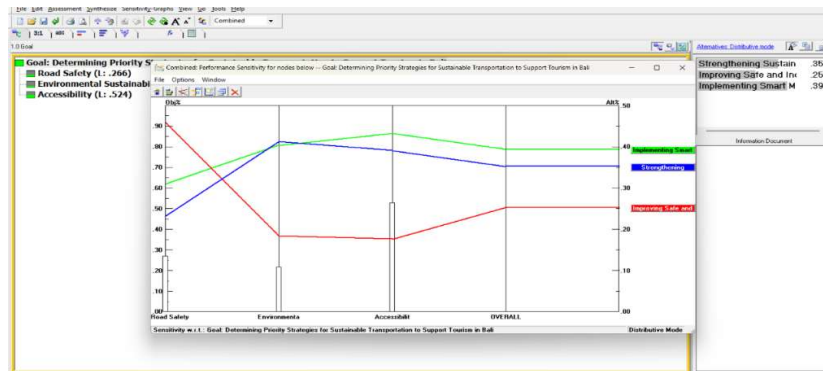


Figure 5. Performance Sensitivity Analysis

CONCLUSION

Based on the results of the AHP analysis, the development of sustainable transportation in Bali needs to be directed at strengthening public transportation, integrating *smart mobility*, and increasing accessibility as the main strategy. This approach is expected to be able to increase the efficiency of tourist mobility while supporting a safe, environmentally friendly, and increased accessibility.

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