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MaaSAcco: Infrastructure System Ensuring Eco-Friendly Tourism by Implementing Mobility as a Service and Sustainable Accommodation

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Abstract

Tourism significantly contributes to ASEAN's economic growth, accounting for 12.1% of GDP and providing 42 million jobs before the COVID-19 pandemic in 2020. However, the sector is responsible for 8% of global greenhouse gas (GHG) emissions, primarily from transportation (49%) and accommodation. Increased tourist numbers have led to higher CO2 emissions due to inadequate public transport systems and energy-intensive accommodations. MaaSAcco offers a strategic solution for sustainable tourism by integrating transportation and accommodation into a comprehensive infrastructure ecosystem. Mobility as a Service (MaaS) unifies transportation modes such as buses, trains, and bicycles, enhancing connectivity and accessibility by 57%. Features like centralized payment, route optimization, and scheduling encourage public transport use, reducing private vehicle reliance and lowering carbon emissions by 47%. Sustainable accommodation in the MaaSAcco system incorporates green building principles, renewable energy, and waste management. These practices reduce carbon emissions by 35%, water use by 30–50%, and waste by 50–90%. MaaSAcco's implementation supports environmental sustainability while offering economic benefits, aligning with Sustainable Development Goals 8 (Decent Work and Economic Growth) and 11 (Sustainable Cities and Communities). It demonstrates a viable path to reducing tourism's environmental impact and achieving long-term sustainability.

Keywords: Eco-Friendly Tourism; MaaS; Sustainable Accommodation; Green Infrastructure

1. Introduction

Transportation emissions, arising from various modes of travel such as air, road, and sea transport, constitute a significant portion of the tourism sector's greenhouse gas emissions. Among these, air travel stands out as a major contributor due to the high energy consumption associated with airplanes. Similarly, road transport, including cars, buses, and motorcycles, significantly contributes to carbon emissions, particularly in regions with limited or inefficient public transportation options. Additionally, emissions from sea transport, including cruise ships and ferries, further add to the overall carbon footprint of the tourism industry.

Addressing transportation-related emissions requires investments in sustainable transportation infrastructure and initiatives promoting low-carbon travel options. This may entail expanding public transportation networks, incentivizing the use of electric vehicles, and implementing policies to reduce air travel emissions, such as carbon offsetting programs. Furthermore, the accommodation sector contributes significantly to emissions through energy-intensive amenities like air conditioning, heating, lighting, and water heating in hotels, resorts, and other lodging facilities. Moreover, the 5 construction and operation of large-scale accommodation developments can result in habitat destruction, biodiversity loss, and increased resource consumption.

To mitigate emissions from the accommodation sector, adopting energy-efficient technologies, implementing renewable energy sources, and promoting sustainable building practices are imperative. Additionally, encouraging eco-friendly practices among tourists, such as reducing water and energy consumption during their stay, can contribute to lowering the environmental impact of accommodation facilities. In conclusion, addressing the environmental impact of the tourism sector necessitates a comprehensive approach involving improvements in transportation infrastructure, adoption of sustainable practices in accommodation facilities, and promotion of responsible tourism behavior among travelers. Through these measures, the ASEAN region can continue to benefit economically from tourism while minimizing its contribution to climate change and environmental degradation [1].

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2. Literature Review

2.1. Mobility as a Sevice

Mobility as a Service (MaaS) is a user-oriented multimodal transportation service integration approach [2]. MaaS generally takes the form of an application or website that is easily accessible to the public. As population density increases, MaaS functions as a faster and cheaper mobility alternative to existing mode options.

MaaS can integrate travel planning, transportation service reservations, electronic ticketing, and payment services between all modes of transportation, both public and private [3]. Through MaaS, users can also choose various modes of transportation from various providers according to their individual needs. MaaS also provides integrated payment services, mode schedules and routes, so that it will be easier for users to choose services that suit their individual needs and preferences.

The most important component is cooperation between all stakeholders, where a balance is needed between the government's interest in public welfare and the private sector's interest in profit. The government plays an important role in defining the vision and performance assessment indicators of MaaS, as well as encouraging investment. The government also plays a role in ensuring security, accessibility, and inclusiveness in the implementation of MaaS. The private sector plays a role in supporting MaaS operations and can benefit from advertising and visibility that increases brand awareness.

2.2. Mobility as a Service

2.2.1. Mobility as a Service

Passive House design theory is based on a comprehensive approach to building construction that aims to achieve superior comfort levels with minimal energy consumption. The concept is based on five key principles: superinsulated envelopes, airtight construction, high-performance glazing, thermal-bridge-free detailing, and heat recovery ventilation. These principles are interconnected and must be considered holistically to ensure the effectiveness of the passive house design. Superinsulated envelopes involve the use of high-performance insulation materials to minimize heat loss and gain. Airtight construction ensures that the building is sealed to prevent air leaks, which can significantly impact the energy efficiency of the building. High-performance glazing is used to optimize the use of natural light while minimizing heat loss and gain. Thermal-bridge-free detailing eliminates weak spots in the insulation, ensuring that heat is evenly distributed throughout the building. Heat recovery ventilation systems are used to recover and reuse heat from exhaust air, reducing the need for additional heating or cooling.

Passive House buildings are designed to consume up to 90% less heating and cooling energy than conventional buildings. They are considered the most rigorous voluntary energy-based standard in the design and construction industry, applicable to almost any building type or design. Passive House buildings are praised for their efficiency due to their high level of insulation and airtight design. They are also eco-friendly, using extremely little primary energy and leaving sufficient energy resources for future generations without causing any environmental damage.

2.2.2. Waste and Water Management

Waste and water management are critical aspects of sustainable development, focusing on the responsible collection, treatment, and disposal of waste and the management of water resources. The practices aim to minimize the negative impact of waste and water on the environment while ensuring the health and safety of the public. Waste management involves several key practices, including waste reduction, recycling, and safe disposal. Waste reduction focuses on minimizing the amount of waste generated at the source through practices such as source separation, composting, and the use of reusable products. Recycling involves the collection and processing of waste materials for reuse, reducing the need for new raw materials and conserving resources. Safe disposal of waste is achieved through landfills, incineration, or other methods that minimize the environmental impact of waste.

Water management involves the responsible use of water resources, including collection, treatment, and distribution. Water conservation practices, such as waterefficient irrigation and the use of low-flow fixtures, help to minimize water usage and reduce the strain on water resources. Water reuse involves the collection and treatment of wastewater for reuse in various applications, such as irrigation and industrial processes. The protection of water quality is essential for maintaining the health of aquatic ecosystems and ensuring the safety of drinking water. This is achieved through regulatory measures and best management practices, such as the implementation of water treatment plants and the use of green infrastructure to manage stormwater runoff.

2.3. Mobility as a Service

An emission-free zone policy is a set of regulations and initiatives aimed at reducing emissions, particularly in urban areas. This policy involves creating zones where only vehicles with low or zero emissions are allowed to operate. The goal is to improve air quality, reduce greenhouse gas emissions, and promote sustainable transportation. Low Emission Zones (LEZs) are a common type of emission-free zone policy. These zones restrict the use of high-emission vehicles, such as those with higher emission classes, by either charging a fee or banning their entry. LEZs can also have different sizes, pricing structures, and operating models, depending on the specific needs and goals of the city. The presence of non-car alternatives, such as public transportation, cycling,

and walking infrastructure, can also contribute to the effectiveness of LEZs in reducing emissions and improving air quality.

Another type of emission-free zone policy is the Zero Emission Zone (ZEZ), which only allows the entry of vehicles that emit no polluting substances, such as battery electric or hydrogen fuel cell vehicles. ZEZs are more stringent than LEZs, as they exclude all vehicles with internal combustion engines, including plug-in hybrid vehicles in some cases. Emission-free zone policies have been implemented in various cities worldwide, with over 320 low-emission zones operating in Europe as of 2022. These policies can be complemented by other measures, such as incentives for low- and zeroemission vehicles, the promotion of alternative modes of transportation, and the development of green infrastructure to support sustainable mobility.

3. Research Method

Data for this research was collected from various sources, including a literature review which includes previous research journals to increase the author's insight in creating innovative solutions that resemble or innovate solutions that have never been implemented before.

For analysis purposes, because the selected research area is Bali Province, data will be obtained from the official website of the Bali Provincial Government and the Bali Province Central Statistics Agency (Badan Pusat Statistik) to obtain relevant information about the condition of the tourism area there and its population.

The data that will be collected are:

1. Current condition of the transportation network in Bali
2. Number of private vehicles in Bali (current condition)
3. Amount of water use in Bali (current condition)
4. Amount of waste in Bali (current condition)
5. Amount of CO2 emissions in Bali (current condition)

After the data is collected, the data will then be analyzed to measure whether the solution is feasible to be implemented in all tourism areas in ASEAN countries. The analysis methods are:

1. Connectivity analysis
2. Reduction of private vehicles analysis
3. Reduction of water use analysis
4. Reduction of waste cost analysis
5. Reduction of CO_2 emissions

The analysis will be done in one of tourism areas in ASEAN countries as the research location. The tourism location that the authors chose was Denpasar City in Bali, Indonesia.

There will also be a calculation of proof if the formulated solution is successful in achieving Sustainable Development Goals (SDG) no. 8 and 11.

4. Results and Discussion

4.1. Increase of Connectivity

The addition of public transport modes also increases the connectivity between tourist destinations in Bali area. Current available routes and underwhelming amount of public transportation that only passes through certain destinations. MaaSAcco offers several modes of transportation that can access destinations that were previously difficult to access by public transportation, so that they are connected to an integrated transportation network.

4.2. Reduction of Private Vehicles

The proposed solution is an effort to divert tourists to use public transportation and reduce car and motorcycle dependency. Based on the calculations shown in Appendix 6, MaasAcco reduces private vehicle usage up to 68,05%, with 50% for cars and 70% for motorcycles. With its implementation, MaaSAcco is forecasted to be able to divert 72,48% of tourists from private to public transportation.

4.3. Reduction of Water Use

Three things are implemented in sustainable accommodation to reduce water usage: rainwater harvesting, efficient water fixtures, and grey water treatment. Analyzing the potential of rainwater that can be harvested for water conservation requires rainfall parameters measured in mm and the area of the roof. Based on data from the Bali Central Bureau of Statistics (BPS), during the rainy season, rainfall can reach 615.9 mm per month. The calculation of the volume of water generated by rainwater harvesting can be seen in the Equation 1.

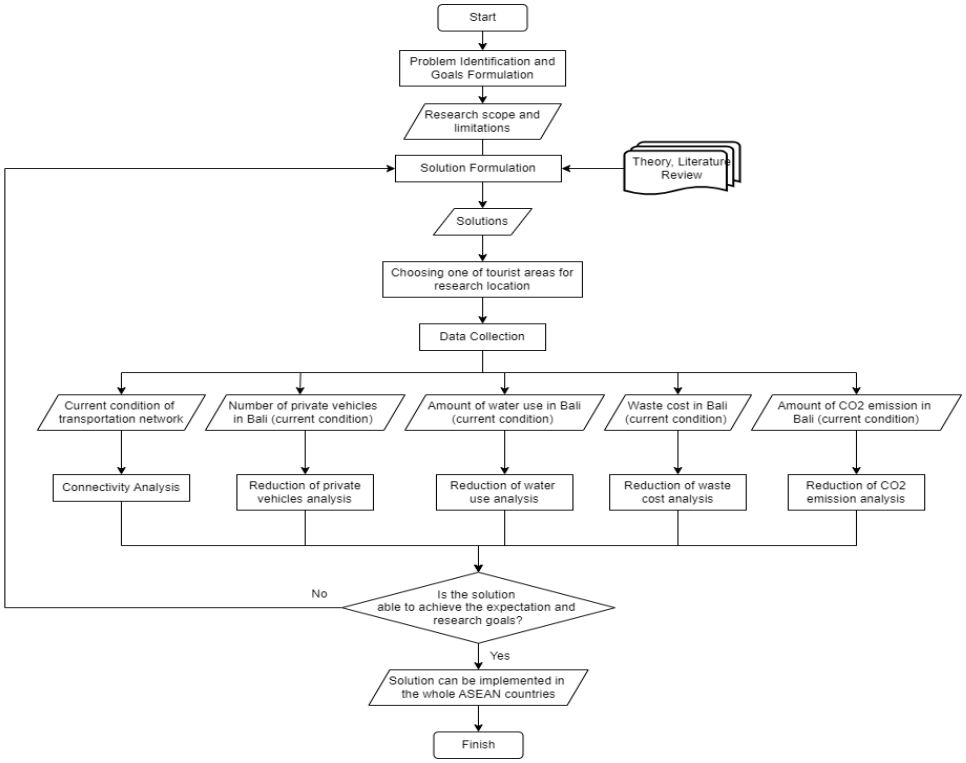

Figure 1. Research Flowchart

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{615.9}{24}\left(\frac{24}{2}\right)^{\frac{2}{3}} = 4.48\ mm/hour = 0.0048\ m/hour \quad (1)$$

$$Q = C.\ I.\ A = 0.95 \times 0.0048 \times 1568.16 = 6.68\ m^3$$

where I = rainfall intencity (mm/hour), t = rainfall duration (2 hours), R_{24} = rainfall per day, Q = incoming debit, C = 0.95, A = area of roof that assumed 1568.16 m2.

As per the Sustainable Hospitality Alliance, hotels typically consume an average of 1,500 liters of water per room daily. Considering the area of the building that has 3 floors, it is assumed that there are 30 rooms. So the estimated water consumption per day is 45,000 liters or 45 m3. Thus, implementing rainwater harvesting can cover around 15% of total water consumption.

Apart from rainwater harvesting, another system implemented is the installation of efficient water fixtures. Based on BRANZ (2008) the average water use in the dry and rainy seasons for toilets and taps is 18.5% and 13.5% respectively. Many older cisterns tend to consume excessive amounts of water, often using up to 12 liters, which is quite common. To mitigate water wastage, consider replacing these inefficient cisterns with modern dual-flush models that utilize either 6/3 liters or 4.5/3 liters for flushing. Another effective method for reducing water consumption is the installation of aerators on taps. By adding an aerator to a handwashing tap, the flow of water is reduced while still ensuring an ample supply. These relatively affordable devices significantly lower water flow rates from approximately 18–28 liters per minute to just 6, 8, or 12 liters per minute.

Thus, installing an efficient water fixture can provide a reduction in water consumption of around 15%. By combining rainwater harvesting, efficient water fixtures, and greywater treatment, water consumption can be reduced by more than 30%.

4.4. Reduction in Waste

According to Attachment 3, there were already twenty locations of TPS 3R (*Tempat Pengolahan Sampah* Reduce-Reuse-Recycle) throughout the Denpasar City in 2022. The table shows that the average amount of waste that can be managed with the 3R method was around 70% from the total of waste entering the TPS. Therefore, it can be concluded that, if this waste management method is applied in every sustainable accommodation in, it is able to reduce around 70% of waste produced.

4.5. Reduction of Carbon Emission

The decrease of private vehicles used will also affect the carbon emissions produced. The calculations shown in Attachment

6 reveal that the MaaS in MaaSAcco can reduce CO_2 emission by 67,3%, from 626 tons to 204,71 tons by utilizing MaaS along with collaboration and proper oversight by the Government. Besides that, Attachment 7 shows that passive house design concept and waste management in the Sustainable Accommodation sector can reduce CO_2 emissions by 70% and 5% respectively. Therefore, the whole MaaSAcco concept can reduce up to 43% CO_2 emissions.

4.6. Financial Analysis

According to Attachment 4 and 5, with 10 years of construction and implementation of MaaSAcco starts from 2025, the payback period will happen in the eleventh year, which is 2035.

4.7. SDG No. 8

The implementation of MaaSAcco can be an effort to realize Sustainable Development Goals No. 8: Decent Work and Economic Growth. Here are the targets and evaluations of MaaSAcco solutions.

Table 1. SDG 8 Target and Evaluation

Target		Evaluation
8.1	Sustainable Economic Growth	The integration of sustainable transportation and accommodation solutions can facilitate and serve as a unique attraction for eco-tourists, leading to an increase in GDP.
8.4	Improve resource efficiency in consumption and production	MaaSAcco implements several measures to enhance resource efficiency, including water and electricity
8.6	Promote youth employment, education, and training	Empowering young people is crucial in supporting the promotion of the eco-tourism concept, particularly leveraging their proficiency in mastering social media.
8.9	Promote beneficial and sustainable tourism	Tourism plays a significant role in the GDP of countries, especially ASEAN nations. Therefore, MaaSAcco can provide effective promotion and benefits for the GDP.

4.8. SDG No. 11

The deployment of MaaSAcco can be an effort to achieve Sustainable Development Goals No. 11: Make Cities Inclusive, Safe, Resilient, and Sustainable. Here are the targets and evaluations of MaaSAcco solutions

5. Conclusion

MaaSAcco, a strategic solution consists of Mobility as a Service (MaaS) and Sustainable Accommodation is the best solution to achieve eco-friendly tourism in ASEAN countries. MaaSAcco can reduce up to 43% CO_2 emissions in the tourism area. By starting the implementation of MaaSAcco in 2025, the payback period will happen in the eleventh year of development which is in 2035. MaaSAcco is the best solution to contribute for ASEAN countries in achieving SDG no. 8 and 11.

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