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REVIEW

The application of Life Cycle Assessment to achieve sustainable tourism: A literature review

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Abstract. Increased development of tourism-related infrastructure to meet the needs of tourists visiting tourist destinations causes greater environmental problems such as greenhouse gas emissions, higher amount of waste, liquid waste as well as sanitation and aesthetics issues. Therefore, it is necessary to evaluate the environmental aspects of tourism activities using environmental performance indicators. The basic idea of the environmental performance evaluation framework is to identify and assess to facilitate continuous improvement and prevent further environmental degradation. The Life Cycle Assessment (LCA) can apply to find tourism activities that have negatively impacted environmental sustainability. Determination of environmental impacts using LCA is a method that can thoroughly identify the stages in tourism activities that can generate environmental impacts. LCA can find the amount of carbon footprint generated by tourism activities, the sector that has the most impact on the environment and the best alternative to realize sustainable tourism.

Keywords: sustainable tourism; life cycle assessment; environmental sustainability

1. Introduction

Tourism is a topic that must be addressed in order to achieve sustainable development. Sustainable tourism development will strengthen the tourism sector's competitiveness by prioritizing the issue of sustainable consumption to address environmental sustainability issues. The cooperation of all interested parties is needed to achieve sustainable tourism. This condition is also necessary because tourists' interests are evolving toward sustainable tourism services and more responsible consumption practices in tourism activities (Streimikiene et al., 2021).

However, it has not been carried out systematically (Guilarte & Quintans, 2019). Increasing the development of tourism infrastructure to meet the tourists' satisfaction when visiting a tourist destination also impacts the environment. There has been an increase in greenhouse gas emissions, an increase in untreated solid and liquid waste, as well as aesthetic and sanitation problems (Ahmad et al., 2018; Balsalobre-Lorente et al., 2020; Jermsittiparsert & Chankoson, 2019; MacNeill & Wozniak, 2018). Immediate actions must be taken in order to achieve sustainable tourism including reducing waste, implementing recycling, saving energy, and increasing tourist awareness to protect the environment (Loureiro et al., 2021). A code of ethics

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in tourism practice will increase parties' willingness to engage in sustainable tourism activities. Waste management, efficient energy, and water supply systems are further concerns, especially in confined areas. In addition, there is a need for environmental certification for tourism managers, increasing population awareness in environmental management, and adaptation plans to climate change (Ivars-Baidal et al., 2021).

A practical design is needed to improve the understanding of sustainable tourism management so that it does not clash with or cause conflicts of interest with the fulfillment of the economic aspects of the local area (Ivars-Baidal et al., 2021). Several problems arise because tourism activities are traditionally managed (paying more attention to aspects of cost, length of stay of tourists, tourist satisfaction, etc.) without paying attention to the need for environmental management. This condition causes high waste generation, low recycling rates, and the absence of environmental protection activities by related parties. At the same time, the government relies on the tourism sector to encourage development and boost the economy (Torres-Delgado et al., 2021).

Tourism activities are closely related to environmental issues so that they require the application of sustainable development principles (Soratana et al., 2021c). Sustainable tourism must be adopted for all tourist destinations by referring to the principles of sustainability, namely environmental, socio-cultural and economic aspects. Environmental resources can be utilized optimally in tourism development by maintaining ecological conditions and preserving biodiversity. In addition, tourism activities need to ensure the authenticity and sustainability of the socio-cultural community and the economic goals of tourism activities for the local community (UNWTO, 2021).

The issue of sustainability in tourism can be viewed from the perspective of the community and stakeholders, as well as economic, cultural, and methodological challenges in responding to the need for sustainability. Tourism is a promising industrial sector because it boosts employment and the economy. However, there are still few sustainable practice approaches that can demonstrate their relationship with environmental sustainability. In comparison, tourism combines numerous economic activities such as attractions, entertainment, hotels, transportation, etc (Budeanu et al., 2016). Ecotourism is one of the initiatives designed to promote responsible travel in order to preserve the environment, improve the population's welfare, and involve educational activities. However, in reality, many ecotourism practices are carried out superficially by using the word 'green,' despite the fact that they prioritize profit over ecological considerations (Soratana et al., 2021b). Among the tourism aspects that tourists take into their consideration are the attractions, accommodation, restaurants/cafes, souvenirs, transportation and other tourism activities. Using the LCA approach on these six components of tourism services can enhance the efficiency of resource consumption and help reduce inefficient costs and minimize other consequences. Applying LCA to these components will result in a more sustainable development than if it was separately done in each sector (Soratana et al., 2021d).

LCA is an excellent tool for balancing the pillars of environmental sustainability. According to The International Organization for Standardization (ISO) in series 14040, LCA measures the consumption of life cycle resources and the contribution to the environmental impact of a product, process, service, and even large systems. The first step in LCA is to determine the objectives and scope, which is followed by life cycle inventory (LCI), life cycle impact assessment (LCIA), and ultimately interpretation of the process. In this method, the inputs and outputs of a product's life cycle process will be analyzed and converted into environmental impacts. All of the environmental effects will be calculated by emission conversion factors (Hauschild, 2018).

An example of determining the purpose and scope of a tourism LCA is identifying the transportation to and from a location, including accommodation activities, restaurants, and visiting tourist attractions. Afterwards, during the life cycle inventory (LCI) phase, data is collected from various sources for tourist activities and links it to existing environmental data sources (e.g.,

from USEPA) to track the amount of water, energy and carbon used. Furthermore, a life cycle impact assessment (LCIA) is performed in measurable impacts. For example, measuring greenhouse gas emissions from electricity in hotel rooms can be converted to the potential for global warming. The correlated LCI and LCIA results are then interpreted for decision making. Because the conversion results are not generally known to the general public, it is compared with an easier-to-understand explanation. For example, CO_2 conversion from hotel rooms is reported in the number of trees that must be planted to absorb CO_2 (Soratana et al., 2021a).

Previous research has implemented LCA on an area in Leuven, Belgium. This is a medium-sized area, but it is a destination for education from various regions and countries and one of Belgium's leading tourist destinations. This study has also identified the consumption behavior of immigrants which showed a significant impact on the urban environment. The study compared immigrants consumption with the consumption patterns of permanent residents to produce policy recommendations for reducing the impact of their activities on the environment (Mirabella & Allacker, 2021). Another LCA study has also been conducted in the City of Vienna, Austria, using the Organizational LCA (OLCA) approach. This method can estimate the potential environmental impacts associated with public services and development activities carried out in the city. This study indicated that 75% of greenhouse gases came from public services that were outside of the responsibility of the city government (Cremer et al., 2021).

From the above perspective, this article aims to identify the application of LCA in the tourism industry to provide some insight into the development of LCA applications in the future to realize sustainable tourism, especially to be used as suggestions for tourism activities on an area scale.

2. Materials and Methods

The following relevant articles for this literature review were discovered through the Web of Science database and Scopus using a snowball system. The first search was related to Life Cycle Assessment, followed by terms related to tourism. The inclusion criteria for the article search were specific to the LCA assessment in tourism. Pieces originating from reviews, on the other hand, were excluded; editorials and full-text articles were unavailable. The research was grouped according to the theme and then discussed in depth to understand how LCA may be used as an instrument to achieve sustainable development.

3. Result and Discussion

3.1. Tracing Carbon Footprint from Tourism Sector by LCA

Carbon emissions are the main concern generated by tourism activities in the world. Measurement of global carbon flows related to tourism was carried out in 160 countries. The study found that tourism activity's carbon emissions have increased four-fold over prior estimates (Lenzen et al., 2018). Tourism activity accounted for about 8% of the world's greenhouse gas emissions. Transportation, shopping and food activities in tourism are significant contributors to carbon emissions. The study reported that most of the carbon footprint was obtained from high-income countries. Due to the high intensity of carbon emissions, tourism is projected to continue to contribute to global greenhouse gas emission. This proves that the tourism sector can be one of the significant causes of the climate change mechanism.

An increase in the number of tourists will be followed by an increase in the carbon footprint. A study in Tunisia looked at the trend of mass tourism to prevent the adverse effects of over-tourism (Widz & Brzezińska-Wójcik, 2020). The first phase was an assessment of the life cycle of the tourist destination to analyze the phase of tourism activity development. Then the evolution of tourist destinations was identified and continued with over-tourism risk assessment efforts. The results of the calculations estimated that in 2025 the number of tourists will be twice as large as the total population. This study suggested the need to create new attractions and tourist routes

in neighboring provinces to reduce the accumulation of visitors, adjust policies and legal provisions for tourism management and involve local communities in tourism activities. This corresponded to an increase in tourists in Barcelona, which resulted in an increase in carbon footprint (Rico et al. 2019)). This study was conducted on more than 30 million tourists who visit Barcelona each year. The average carbon footprint was 43 kg CO_2 eq/day for daily tourists and 111.6 kg CO_2 eq/day. The total carbon footprint of Barcelona's tourism activities was about 9.6Mt CO_2 eq/year, representing emissions of 96.9kg CO_2 eq/visitor/day. The primary source of emissions was transportation (95.6%), especially aviation.

In addition, the LCA methodology was applied to various geographic locations in Chile to analyze the environmental impact of tourist accommodation (Ovalle & Muñoz, 2020). The purpose of this study is to evaluate the impact of geographic location on energy demand for thermal comfort, and then to analyze the environmental impact. The data collected was on electricity, fuel, water treatment, wastewater, and solid waste management subsystems. The impact categories were then analyzed with impacts on climate change (kg CO_2 eq). The result showed that cumulative energy demand is different according to geographical condition for the fossil fuel demand category. It was also found in China's Wulingyuan Scenic and Historic Interest Area (Tang et al., 2017). The growth rates of total energy consumption and carbon emissions every year were 15.46% and 15.87%, respectively. Therefore, optimizing the design of the tourism industry (24.67% contribution rate) and decreasing the energy intensity of the tourism industry (20.07% contribution rate) were the two most essential factors in restraining the growth of carbon dioxide emissions.

According to these research, tourism is not a low-impact industry, thus it is only necessary to consider economic sustainability and social welfare. The demand for the development of the tourism sector on a large scale in such a short amount of time will provide a significant environmental burden if it is not balanced with a commensurate ecological policy. This policy needs to be implemented by management and travelers so that they prefer to engage in environmentally friendly tourism activities.

3.2. LCA Environmental Impact of Transportation in Tourism

Transportation is one of the most significant contributors to carbon emissions in tourism activities. The tourism industry in Japan was evaluated retrospectively, starting from the preparation of tourism activities to after the implementation of tourism activities to see the life cycle of tourism services (Kitamura et al., 2020). Life cycle stages were assessed from activities by travel agencies and tour guides, transportation, accommodation, food and beverages and souvenirs. The study reported that 136 million t-CO_2eq of greenhouse gas emissions from the tourism sector were taken into account, mainly from the transportation sector (56.3%), souvenirs (23.2%), accommodation (9.8%), food and beverages (7.5%), and tourism activities 3.0%.

It was also found in tourism activities operating on the coast of Macedonia (Michailidou et al., 2016) where several hotel operations were analyzed. The hotels were assessed for transportation, heating, ventilation, air conditioning systems, hot water production, kitchen operations (cooking utensils, refrigerators, freezers), laundry facilities, lighting, and other electrical devices (TVs, in-room refrigerators, cleaning equipment, and elevators). In addition, tourist travel activities were also considered in the system limits. The results of the LCA calculation found that air transportation contributed the most significant environmental damage, followed by hotels and land transportation.

Another study conducted in the tourist destination of Patong, Phuket, Thailand, assessed the environmental impact caused by tourism activities (Prapasponga et al., 2019). Data was collected from hotels, inns, and tourists. The tourism activities studied were accommodation, mobility, recreational activities, consumption, and waste management. The LCA results found that transportation activities contribute as much as 85% of all environmental impacts due to tourism activities (including long-distance flights, domestic flights and private vehicles) and followed by

the hotel and lodging sector. This condition required an improved pattern of transportation services to improve mobility patterns. Other studies have also found that aviation in tourism activities produces 50%–82% of greenhouse gas (GHG) emissions (Sharp et al., 2016). This figure is expected to continue to increase over time due to increasing tourism promotion and convenience in the transportation sector.

Special emphasis should be put to sport tourism events in order to pay more attention to environmental impacts. Sport tourism also has a significant environmental impact on the transportation sector. A study examined the carbon footprint of the March Madness basketball tournament in the United States as one of the goals of sports tourism. This study found that the total number of tourists visiting this event is a significant factor in the carbon footprint. The contribution of transportation activities accounted for almost 80% of the total carbon footprint, followed by accommodation (6.83%), food (6.37%), and the operation of sports stadiums (5.9%) (Cooper & McCullough, 2021). Similar conditions also occurred at an international surfing event in Portugal which found that supporters' transportation from various countries became the main contributors to environmental problems (Martins et al., 2021).

Another study found an alternative transportation that does not harm the environment. Research on the LCA of the transportation sector in tourism activities was conducted at the Kuelap Archaeological Complex, Nuevo Tingo city, Peru (Biberos-Bendezú & Vázquez-Rowe, 2020). This area was classified as a remote area, where access to this location is only through a dirt road route, so a cable car system was formed to increase the number of tourists. The LCA method was carried out to compare the two transportation methods available in this area to assess their impact on the environment. In determining the objectives and scope of the LCA, the service life of the two infrastructures was taken into account, which for road use is not significantly different in 20 years. However, the cable car system will be used for 50 years in infrastructure and 20 years for the electromechanical systems. The study results showed that the newly implemented cableway system significantly reduces environmental impacts for all analyzed impact categories, except for freshwater eutrophication.

Since the transportation sector has the most considerable contribution to carbon generation, the tourism sector needs to consider other transportation alternatives in tourism activities, such as mass transportation and additional policies to reduce the use of fossil fuels for the tourism sector. Further modeling is needed regarding the design of alternative modes of transportation for tourism activities to overcome these problems.

3.3 Tourism Energy Efficiency and Carbon Footprint

The LCA study also discovered how tourism can measure their energy efficiency. A separate study analyzed the carbon footprint of luxury hotels in Colombo, Sri Lanka (Abeydeera & Karunasena, 2019). Then data was collected on diesel consumption (for example, for backup power generation), water consumption meter readings, refrigerant supply levels, electricity consumption, gas consumption and details of paper usage. The data was also taken from hotel operation records, equipment maintenance, electricity bill, electricity usage logbook; water bill and logbook with water consumption; and logs and data related to emergency power generation on boilers and chillers. The results of the LCA calculation found that the dominant emission source is from the use of electricity and gas. Large consumption was used to increase guest satisfaction. This is in line with other research in Thailand that conducted an LCA approach in hot spring tourism activities at San Kamphaeng Hot Spring (Chaiyat et al., 2020). The study analyzed the energy costs of the combined cooling heating and power (CCHP) system used in the hot spring. In the unit and absorption and dryer, it was found that the average energy efficiency was 11.6% and 11.2%, respectively. This system was less efficient due to climate change, human toxicity, metal depletion, and the use of fossil fuels.

The LCA model for calculating carbon emissions was also implemented in the Hui cultural destination, Huangshan City (Mi et al., 2020). Carbon emissions resulted from air conditioning, lighting, and water use in accommodation, transportation, eating and drinking, entertainment and shopping. This study found that star hotels produce the highest carbon emissions, so it was recommended to advocate for hotel managers to implement energy efficiency policies.

Table 1. Review of Tourism Impact Using LCA Method

Author	Location	Type of Tourism	Result
Lenzen et al. (2018)	Global (160 countries)	All tourism	Tourism activities account for about 8% of global greenhouse gas emissions.
Widz & Brzezińska-Wójcik (2020)	Tunisia	Mass tourism	2025 the number of tourists will be twice as large as the total population.
Rico et al. (2019)	Barcelona	City tourism	The primary source of emissions in tourism is transportation (95.6%).
Ovalle & Muñoz (2020)	Chile	Tourism accommodation	Energy demand and carbon footprint differ depending on the geographical condition because of the fossil fuel demand.
Tang et al. (2017)	China	Natural heritage tourism	Energy consumption and total carbon dioxide emissions from tourism are 15.46% and 15.87%.
Kitamura et al. (2020).	Japan	All tourism	Greenhouse gas emissions from the tourism sector mainly come from the transportation sector (56.3%).
Michailidou et al. (2016)	Macedonia	Mass tourism	Air transportation contribute the most significant environmental damage, followed by hotels and land transportation.
Prapasponga et al. (2019)	Thailand	Beach tourism	Transportation activities contribute as much as 85% of all environmental impacts due to tourism activities.
Sharp et al. (2016)	Iceland	All tourism	Aviation in tourism activities contributes 50%–82% of GHG emissions
Cooper & McCullough (2021)	United States	Sport tourism - basketball event	The contribution of transportation activities accounts for almost 80% of the total carbon footprint.
Martins et al. (2021)	Portugal	Sport tourism - surfing event	Transportation has become an important component in sport tourism
Biberos-Bendezú & Vázquez-Rowe (2020)	Peru	Archaeological-site tourism	Implementing cableway system in tourism sector significantly reduces environmental impacts.
Abeydeera & Karunasena (2019)	Sri Lanka	Hotel industry	Dominant emission source in accommodation sector is from the purchase of electricity and gas.
Chaiyat et al. (2020)	Thailand	Hot spring	Inefficient heating systems in hot spring baths lead to climate change, human toxicity, metal depletion and the use of fossil fuels.
Mi et al. (2020)	China	Cultural tourism	Hotels produce the highest carbon emissions.

From the studies that have been discussed above, the tourism sector contributes about 8% of greenhouse gases. This will increase as tourism growth is predicted to double from the previous year. All parties involved must work together to solve this problem so that tourism growth after the COVID-19 pandemic may resume. The main goal of tourism recovery is to revive the economic sector hit by the pandemic. As a result, people living around areas that can generate income from tourism may compete to enhance their area, build tourism infrastructure and attract other economic sectors. The orientation of economic recovery should be accompanied by implementing environmental sustainability patterns and making policies to reduce the environmental impact of each phase of the recovery process of the tourism sector.

LCA studies have also revealed that transportation is the highest contributor to environmental impacts, especially air transportation. Greenhouse gas emissions due to transportation activities in tourism are estimated to increase by 25% in 2030. With the continuous development of domestic tourism due to travel restrictions between countries, domestic tourism growth is substantially higher than international tourism growth (35.6 billion domestic tourists and 1.8 billion tourists and 1.8 billion international tourists) (UNWTO, 2019), thus policymakers must consider other alternatives. One solution is to revive mass transportation with minimal air pollution, such as trains that can bring tourists from several regions to the world's tourist hotspots to avoid using fossil-fueled vehicles. Another solution is to maximize the use of mass transportation systems (such as buses) through travel agents to minimize private vehicles to a tourist destination. Mass transportation operations are also required to use alternative fuels that emit fewer greenhouse gases. Parties actively involved in environmental awareness to reduce greenhouse emissions can be given incentives, which will motivate other tour operators to create environmentally friendly tourism programs.

Achieving sustainable tourism requires more in-depth attention to energy issues, especially in hotel operations and tourist attractions. Hotels consume more energy than other commercial buildings, for the sake of guest comfort and satisfaction. However, the main problem lies in the waste of energy, where 42% of the energy used is usually wasted. Most of the waste is caused by system errors and the lack of awareness of the behavior of hotel staff and guests in energy use. Apart from having an impact on the environment, this waste also increases the hotel's operating costs and lowers the expected profit margin (Huddart & Stott, 2020). Energy is also a significant cause of environmental problems such as atmospheric pollution, increased greenhouse gas emissions, and increased potential for acid rain. The trend of environmental sustainability in economic growth in the tourism sector is growing because tourists have started to include 'environmental variables' when deciding which tourist destinations and tourism services will be used at the destination. This serves as a catalyst for tourism services to prioritize environmental protection, particularly energy savings. Tourist service providers need to make several innovations in the process of providing services, products offered to tourists and organizational mindset to save energy in all their activities. Implementing sustainable consumption should be applied to all tourism sectors to encourage energy efficiency reforms in reducing carbon footprints.

Unfortunately, previous LCA research has not captured the overall environmental impact of tourism activities produced by a tourist destination, such as indicators of human health, ecosystem quality and resources (Jouini et al., 2019). From similar research available to date, most environmental impact assessments from tourism activities are only limited to estimating greenhouse gas emissions originating from the life cycle phase of each tourism activity until consumers, i.e. tourists, are satisfied. The majority of research on the environmental impact of tourism examined transportation as the cause of the most significant environmental impact which is more relevant to tourists traveling long distances. Many tourist activities are carried out by domestic tourists who live close to the tourist attractions, and this should be taken into account in more detail. LCA has been widely used in assessing tourism activities. Still, it is necessary to

consider environmental impacts that are appropriate to the region's characteristics, can be applied to other areas, and provide the most accurate and comprehensive technique for measuring the environmental impact of tourism.

4. Conclusion

Tourism could threaten the existing conditions of an area if this activity does not consider the use of existing resources and their impact on the environment. To recommend ecologically friendly tourism activities, a comprehensive strategy is required. LCA in tourism activities is used to accommodate stresses without showing permanent damage. Reducing the environmental impact of tourism needs to be done by applying reliable impact assessment methods. More complex calculations are required to measure the environmental effects of tourism. Whereas applying LCA has more advantages than environmental impact assessment using conventional methods (Filimonau, 2016). Studies with LCA can help answer the problems posed by tourism activities. The analysis is used in every stage of the life cycle of tourism activities. The results can determine the amount of carbon footprint generated by tourism activities, the sector that has the most impact on the environment and the best alternative to achieve sustainable tourism.

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