

Analysis of Potential, Impact and Design of a Sustainable Ecotourism Management System Using an Industrial Engineering Approach in Kuala Bubon Mangrove Forest, West Aceh

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ABSTRACT

The discourse of the West Aceh government and the Ministry of Tourism and Creative Economy, which aims to develop mangrove forest area in Kuala Bubon, West Aceh into an ecotourism site to boost the community's economy, has drawn attention from many parties. This is due to the rich biodiversity present in the mangrove forest. Pre-ecotourism studies need to be conducted to ensure that the use of this forest can be managed properly, including studying potential tourist attractions, analyzing negative impacts, and engineering a sustainable ecotourism management industry. This involves using an industrial engineering approach, which offers an optimal framework for achieving these goals. The research was conducted in Kuala Bubon mangrove forest, West Aceh, in July 2024. Survey techniques and direct observation were used to gather data on the ecotourism potential in Kuala Bubon mangrove forest. This potential data will be mapped using Quantum GIS and then analyzed to assess the potential and impact of environmental damage as part of ecotourism and the ecosystem. The impact of the damage will then be addressed with alternative industrial engineering solutions, creating an effective management design using AutoCAD. The research results identified five ecotourism attraction points: sunset observation ecotourism, flora & fauna exploration, fishing, duck games, and shellfish searching. Based on this potential, a negative impact analysis and industrial engineering of the ecotourism area will be conducted, focusing on three aspects: infrastructure, waste management, and the utilization of renewable energy.

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I. Introduction

The Kuala Bubon mangrove forest is one of the coastal mangrove areas located in Samatiga District, West Aceh Regency. This forest has a high level of diversity due to the composition of the forest and the high availability of food ingredients for coastal fauna. Based on the West Aceh government's program and the Ministry of Tourism and Creative Economy, this mangrove forest is planned to become an ecotourism area, with funds to be distributed amounting to 43 billion [1]. This is an effort to improve the community's economy through the tourism sector. If this discourse is realized, there will be many sources of livelihood for the surrounding community, starting from ecotourism managers, the MSME industry, tour guides and the development of infrastructure to support ecotourism. For this reason, it is necessary to develop clear policies and designs for ecotourism so that its use still takes into account the concept of a sustainable ecosystem as a habitat for flora and fauna.



Kuala Bubon mangrove forest currently has a high level of diversity, this indicates that the ecosystem function in this forest is still very good, where the relationship between species and the environment is functioning properly. Several previous studies have reported biodiversity in this forest, such as birds, fish, aquatic infauna and mangrove plants [2–7]. Conditions like this need to be maintained for the sustainability of mangrove forests which contain a variety of diversity. The discourse of making this mangrove forest an ecotourism area certainly poses a serious threat to the sustainability of the ecosystem. Because, if environmental damage occurs, it will cause the loss of certain species which can disrupt the stability of the food chain. Furthermore, a situation like this will disrupt the lives of all species in this mangrove forest.

Ecotourism areas often become the focal point for industrial development, the rich diversity becomes an attraction for visitors so that many activities will take place and raise several challenges that can damage the ecosystem itself [8][9]. For example, waste produced by ecotourism visitor activities can damage habitat for flora and fauna. Limited infrastructure that supports sustainable ecotourism, such as transportation and waste management facilities, can be an obstacle to the sustainability of this area [10][11]. In this context, sustainable ecotourism becomes very important in efforts to preserve the ecosystem and advance the community's economy. Therefore, ecotourism needs to be managed effectively, through pre-ecotourism studies, using an industrial engineering approach that offers an optimal framework for achieving this goal.

Industrial engineering involves designing, implementing and improving systems to increase productivity, efficiency and sustainability [12]. This industrial engineering ensures that the negative impacts resulting from the use of mangrove forests as ecotourism areas can be minimized through the implementation and strategy of sustainable practices. Risk analysis needs to be carried out as early as possible so that it can be anticipated through appropriate strategies in maintaining the sustainability of ecotourism and the mangrove ecosystem [13]. This pre-ecotourism study needs to be carried out, to answer the challenges and obstacles to developing sustainable ecotourism.

This research is a collaboration between biological science, industrial engineering and Information technology. Biological studies here analyze the potential for biodiversity and mangrove ecosystems as an attraction for visitors. This biological study will provide information for ecotourism managers to highlight the uniqueness and conservation value of the diversity that lives in the Kuala Bubon mangrove forest. Information technology studies will display spatial information on mapping ecotourism potential, while Industrial Engineering studies, namely industrial engineering, are used in designing sustainable ecotourism management strategies to maintain ecosystem sustainability.

Industrial engineering will provide concrete solutions to the problem of developing sustainable ecotourism. This will make ecotourism management operations more focused and controlled. This pre-ecotourism study can be a reference in developing ecotourism, especially as there is a collaboration of scientific disciplines that will solve problems that are often faced in sustainable ecotourism management. Such as environmentally friendly infrastructure construction, controlled visitor management, and efficient waste handling are some examples of sustainable strategies that must be implemented.

II. Method

Data on ecotourism potential was obtained by exploring potential that could become a tourist attraction which includes natural resources and the beauty of mangrove forests. Points with ecotourism potential will be marked with coordinates using the Global Positioning System (GPS). Next, data collection was carried out on physical environmental factors including temperature, pH, and turbidity (Soil tester, thermometer, hygrometer, turbidity meter).

This potential data will be mapped using Quantum GIS and then analyzed for the potential and impact of environmental damage as part of ecotourism and the ecosystem. The impact of the damage will then be prepared as an alternative industrial engineering solution as an effective management design using the Auto Cad Software.

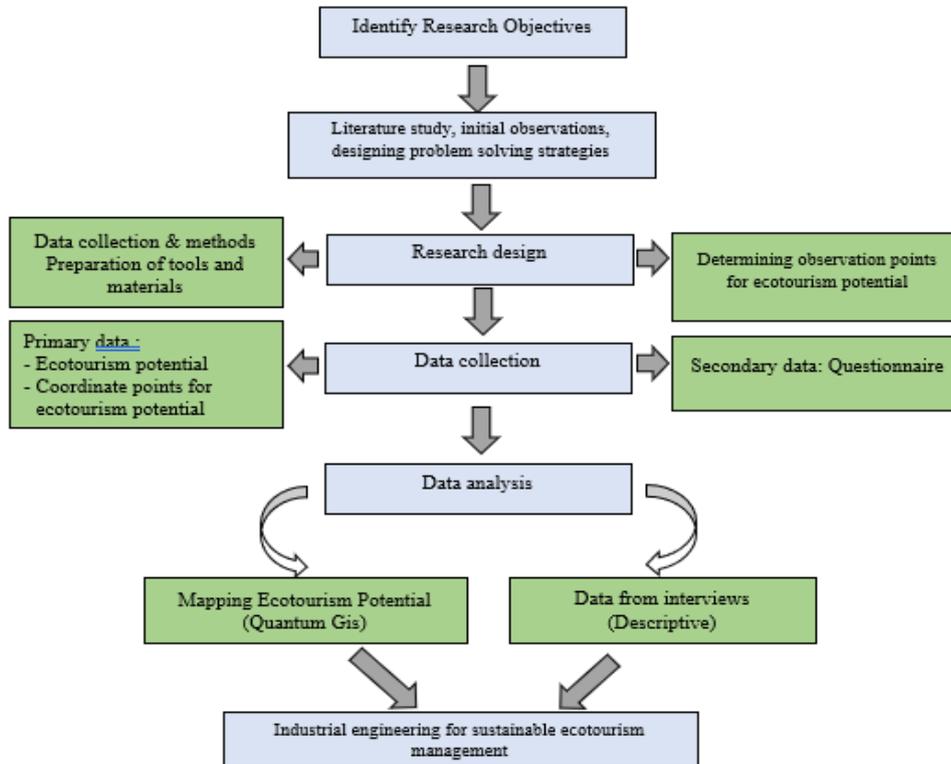


Fig 1. Method

III. Results and Discussion

A. Ecotourism Potential in Kuala Bubon Mangrove Forest, West Aceh

Data on potential ecotourism attractions in mangrove forests was obtained through exploration and the coordinates of locations with ecotourism potential were recorded, then analysis was carried out using Quantum GIS to show the mapping of the distribution of ecotourism potential which could be an attraction for ecotourism visitors.

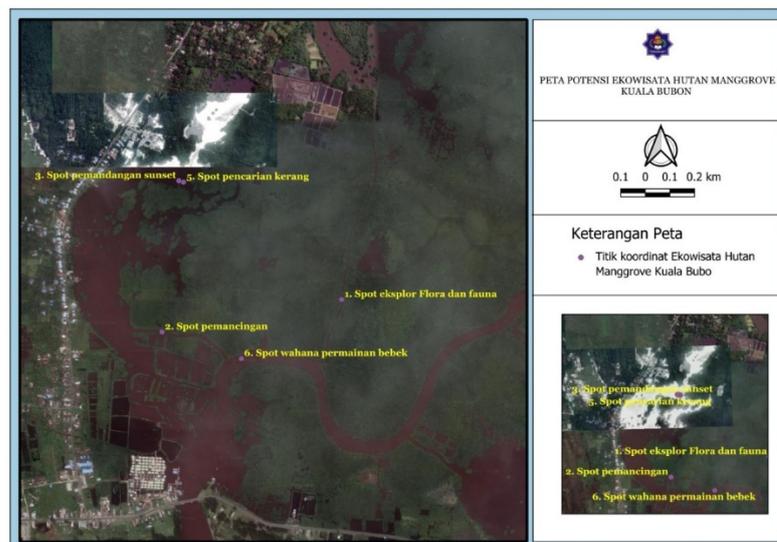


Fig 2. Ecotourism Potential in Kuala Bubon Mangrove Forest

Based on physical factor measurement data, it is known that Kuala Bubon mangrove forest is still maintained in accordance with mangrove condition standards. These results are in accordance with several previous studies regarding the physical condition of the mangrove environment, namely, soil

pH between 6.5-6.8, water temperature 25-30 0C, and water turbidity can reach 50 NTU or even more if the mangrove forest is located around residential areas. and there are many community activities there [14–16].

B. Negative Impacts of Ecotourism in Mangrove Forest of Kuala Bubon, West Aceh

The analysis of interview data conducted with several local residents around the Kuala Bubon mangrove forest area in West Aceh reveals that the majority of the surrounding community works as fishermen in the waters of the Kuala Bubon mangrove forest, utilizing natural resources to meet daily needs such as fishing.

Regarding the utilization of this mangrove forest area as an ecotourism site, the community is aware of the issues concerning the mangrove forest area that are being discussed by the local government of West Aceh and the Ministry of Tourism and Creative Economy. However, some local residents still lack understanding of the concept of sustainable ecotourism, and therefore do not yet know how to manage such ecotourism.

The community's opinions regarding the negative impacts of continued ecotourism include concerns about the potential damage to the mangrove forest ecosystem if the development planning for ecotourism is not managed well. Despite these concerns, the community also hopes that the ecotourism development planning can bring positive impacts to the local residents. Sustainable ecotourism management in the mangrove forest should proceed in line with the expectations of the local community, who are willing to participate in advancing ecotourism, such as by becoming tour guides, vendors, and more.

Ecotourism can have negative impacts on the environment or ecosystem balance, affecting all organisms present. Several studies have shown negative impacts of ecotourism management that does not adhere to sustainable principles [17][18]. Similarly, in the Kuala Bubon mangrove forest, poor ecotourism management can lead to the following negative impacts:

1. Destruction of various flora and fauna habitats directly due to ecotourism activities.
2. Uncontrolled waste management.
3. Damage to flora and fauna habitats due to unplanned infrastructure development and the exploitation of natural resources to meet ecotourism needs.
4. Overall, it is feared that this will lead to ecosystem damage and could disrupt the life of organisms.

C. Industrial Engineering of Ecotourism Management in the Mangrove Forest of Kuala Bubon, West Aceh

Industrial engineering is an approach within Industrial Engineering that involves designing, managing, and evaluating the productivity and sustainability of a system or organization [12]. The goal is to make a system more effective and efficient, minimize damage, and optimize resources. In the context of ecotourism management, the industrial engineering approach is used to build and manage sustainable ecotourism systems, such as infrastructure design, waste management, visitor management, and other practices to address the negative impacts of ecotourism activities that tend to harm the environment. This approach involves carefully planned, science-based, and environmentally friendly solutions. Industrial engineering in ecotourism management includes:

1. Development of environmentally friendly infrastructure: Building designs should prioritize environmental conservation as the main goal of tourism. The design should ensure that building construction does not harm the environment and that energy sources are used to avoid carbon emissions [19][20].
2. Waste and byproduct management: Industrial engineering provides optimal waste management designs to prevent environmental damage and manage waste products from visitor activities. For instance, in the Pahawang tourism area, Styrofoam waste is utilized [21]. Such management practices need to be planned and implemented in ecotourism areas to maintain environmental sustainability.
3. Renewable energy can be utilized in the development of ecotourism, especially in coastal areas with sufficient wind resources, by using wind turbines, which are a clean, abundant, and renewable energy source, This reduces dependence on fossil fuel-based energy [22][23].

Industrial engineering for sustainable ecotourism management can be seen in the following Figure.

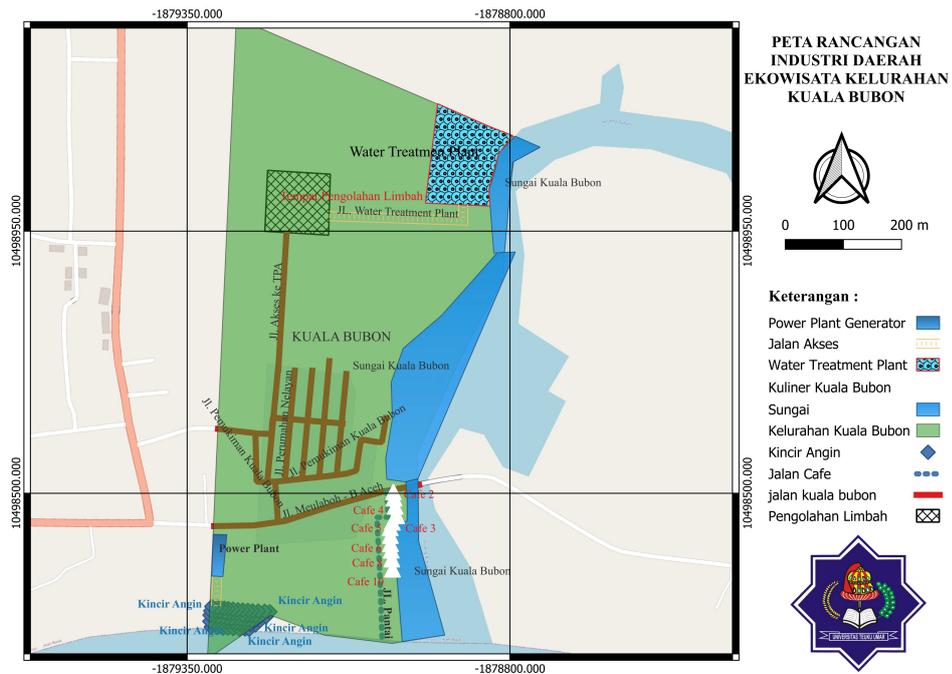


Fig 3. Industrial engineering for sustainable ecotourism management

IV. Conclusion

The research results show the potential for ecotourism in the Kuala Bubon mangrove forest, West Aceh, which has been coordinated and mapped using the Quantum GIS application, such as the potential for ecotourism in sunset views, shellfish harvesting, fishing, flora and fauna exploration, and duck games. Ecotourism activities will have a negative impact on the sustainability of the ecosystem so that it will threaten all living creatures in it. Industrial engineering of ecotourism areas as sustainable ecotourism management, including the placement of ecotourism supporting infrastructure, waste processing facilities and the use of renewable energy, is important as an effort to maintain the sustainability of ecotourism areas.

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