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Sustainable development of Depok Beach, Yogyakarta: System dynamics approach to waste management and maritime economy enhancement

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Abstract. Depok Beach is a tourist destination in Yogyakarta which has experienced significant development as part of the South Coast National Tourism Strategic Area of Yogyakarta. However, waste management is still the main challenge faced. The objectives of this study is to build a sustainable model for Depok Beach, to estimate the behaviour of the management system, and develop a strategy to promote the maritime economy in the. System dynamics was used for modelling the management strategy. Data were collected through observation and in-depth interviews with related stakeholders. The results showed that Depok Beach will continue to attract more tourists until 2030, but a decrease in visitor numbers is expected to occur after that. It is due to a decrease in the attractiveness value of the beach. Meanwhile, a comprehensive and integrated approach of policy implementation scenarios is needed to yield significant results. The development of Depok Beach required a comprehensive, integrated policy approach.

Keywords: Marine tourism; Sustainable tourism management; System dynamics

1. Introduction

The South Coast of Yogyakarta is a leading tourist destination in the Special Region of Yogyakarta (DI Yogyakarta), designated as a National Tourism Strategic Area. This designation is based on Government Regulation Number 50/2011 regarding the Master Plan of National Tourism Development for 2010-2025. Furthermore, the Provincial Government of DI Yogyakarta reinforced the tourism development strategy through the Special Region of

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Yogyakarta Regulation Number 1/2019, an update on the Master Plan of Regional Tourism Development 2012-2025 in Yogyakarta dated back in 2012. The South Coast of Yogyakarta possesses various tourism potentials, including potential resource on natural tourism, adequate access, the availability of cellular networks, a fish market auction, and a windmill for energy generation [1]. This region is renowned for several tourism interes, such as the legend of Ratu Kidul, a seafood culinary centre, and a maritime regional development, not to mention rich and diverse potentials for unique cultural, natural, and artificial tourist attractions. The interaction between the Special Region of Yogyakarta and its surrounding areas, especially Solo and Semarang presented further growth potential in the South Coast of Yogyakarta [2].

Depok Beach is a popular tourist attraction on the South Coast of Yogyakarta which was initially a fishing village [3]. The tourist attraction on this beach offers unique and diverse experiences for visitors. It features activities like beautiful beach views, fish landings, fish auctions, fish sales, fish-based culinary delights, light aircraft attractions, kite festivals, and souvenir sales. Additionally, the beach hosts an annual festival, attracting even more tourists [1]. Due to its many attractions, Depok Beach is a source of income for local fishermen and plays an essential role in the economy of the communities. Tourism development in the area is expected to boost the quality of community welfare. Tourism is known to have various positive impacts on economic growth, such as job creation, increased local income, and motivation for increased production [4]. However, fully utilizing the tourism potential of Depok Beach requires a strategic approach that balances economic growth, coastal tourism, and local community involvement [5].

The development of Depok Beach as a premier tourist attraction on the South Coast of Yogyakarta still faces various challenges, particularly related to tourism sustainability. With growing pressure to conserve natural resources, the importance of tourism sustainability must be addressed [6]. The study by [7] explained that the development of Depok Beach provides economic benefits even though inadequate waste management threatens the environment. Other issues that persist in the development of this beach include a need for more attention to cleanliness, reduced community involvement in environmental management, and suboptimal management of coastal tourist areas [1,3]. To address these challenges, the development strategy for Depok Beach needs to strike a balance between all sustainability considerations.

Determining the strategy for developing the potential of the South Coast of Yogyakarta must be done comprehensively and measurably. Also, the development strategy for Depok Beach needs to be monitored constantly to avoid various risks, such as local community rejection and project failure [8]. Determining the right strategy to prevent negative consequences, including increased population density, declining residents' living standards, high demand for goods and services, pollution, and destruction of natural resources [9]. Also, the interdependence between social, economic, and environmental systems with their impact on sustainability must be considered [10]. This complexity only adds to the challenge of formulating a development strategy for the tourism area of Depok Beach.

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There are several studies on the sustainability of tourism in coastal areas, but the majority still need to provide a comprehensive understanding of the relationship between the involved variables. Determining a sustainable development strategy for Depok Beach through understanding the complexity of the tourism management system can be achieved through system dynamics modelling. The modelling is used to comprehend complex systems, understand the sources of policies, and design more policies [11]. System dynamics can also help comprehend the impact of various factors on the defined goals [12,13]. Furthermore, the modelling serves as a decision-making tool for tourism decision-makers and regulators to develop strategic and operational policies at various levels [14]. System dynamics can also estimate the impact of policy interventions through simulations [15]. It is recommended to promote a holistic understanding of complex problems and assist in the development of more effective policies. According to the study conducted by [14] emphasized that the use of system dynamics in the tourism sector still needs to be improved. Therefore, this study aimed to model the sustainable management of Depok Beach tourism objects, estimate the behaviour of the tourism management system, and develop a sustainable strategy to promote the maritime economy in the South Coast of Yogyakarta as well as its environment. The Depok Beach tourism management model simulation is expected to offer suggestions for more effective development strategies that minimize the risk of project failure.

2. Methods

System dynamics formulated, simulated, and validated a model that produced a well-designed and feasible policy plan. It is explicitly designed to analyse complex physical, social, and economic systems. Also, system dynamics has been applied to various sustainability issues, such as development programs, water resources, environment, and urbanization [16–21]. This study adopted system dynamics to model and simulate a sustainable strategy for managing Depok Beach. Historical data on 2014-2019 from Central Bureau of Statistic were essential information for the simulation and forecast. Data processing was performed using Vensim PLE Software. The dynamic interaction between social, economic, and environmental factors was complex and characterized by nonlinearity and feedback loops. Simulating these interactions and conditions was crucial for promoting coordinated and sustainable development. The results of this study could serve as a guide for the future development system.

Furthermore, the model used in this study was designed for the specific conditions at Depok Beach. It was constructed based on the mental model of the researcher, respondents, and previous studies. These factors made the results unique and distinct from similar studies conducted in other locations. The effectiveness of the system dynamics modelling depended heavily on the researcher's ability to accurately produce the actual system in the model. According to [22], system dynamics was a conceptual tool for understanding complex systems. It involved analysing a situation, examining the behaviour and structure of the system, as well as understanding its components [23]. This approach helped study complex problems such as sustainable development [24]. The process of system dynamics consists of four stages: observing reality, conceptual modelling, interpretation, and using the modelling results [17].

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2.1. Preparing the concept model

System dynamics modelling was developed through a literature study to identify actual conditions. Sustainable tourism is about social, economic, environmental, and institutional interaction.

2.2. Preparing the model structure

System dynamics modelling was illustrated in a causal loop diagram (CLD) and a stock and flow diagram (SFD) after it was obtained. CLD was based on the mental model of the researcher and various related references. The causal relationships between variables are depicted through arrows, with a positive sign (+) and a negative sign (-) indicating an opposite effect on others.

2.3. Stimulating the model

The simulation was a way of imitating the behaviour of a phenomenon or process. Therefore, the purpose of the simulation was to understand the phenomenon or process being modelled, analyse and optimize its behaviour, and predict the future. The simulation involved inputting data and information into symbols in the system dynamics model, such as stocks (level), flows, and constants (auxiliary).

a. Entering data into SFD. From BPS for 2014 – 2019, the number of tourists, user fees, environment, and others were the secondary data.
b. Data were administered as stock (level). Incomplete reference data were filled with extrapolation and interpolation techniques which were tested by calculating the correlation coefficient.
c. Other data were registered as additional (auxiliary). The method of entering data was carried out in two ways: graphical and mathematical. Mathematical relationships were applied to the model.
d. Other data were also registered as constants, such as time series.

2.4. Analyzing the model sensitivity

Sensitivity analysis is performed to find out how sensitive a variable is to other variables. Sensitivity analysis is also used to test the suitability of models to real-world conditions [25]. Sensitivity analysis in this study was conducted to see the impact of changes in tourist number after several scenarios. Sensitivity analysis in the study was carried out by changing the value of a system variable from 2021 to 2040. The scenarios that will be carried out includes:

a. 1st Scenario Increased waste carrying capacity.
   The implementation of the scenario is carried out by increasing waste treatment capacity by 5 percent. Increasing waste treatment capacity can directly or indirectly affect the quality of tourism management and can increase the number of tourist visits [26].
b. 2nd Scenario
   Scenarios related to social problems are carried out by reducing the value of social problems by 5 percent in the model built. Reducing social conflicts can effectively affect the development of a tourist destination [27].
c. 3rd Scenario

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The third scenario is to combine the first and second scenarios at one time. This is done to see the impact that occurs if both scenarios are carried out simultaneously. The development of complex strategies can generally have a greater positive impact [28].

3. Result and discussion

3.1. Overview of Depok Beach management

Depok Beach is located in Kretek, Bantul Regency, a popular tourist attraction on the South Coast of Yogyakarta, designated as a National Tourism Strategic Area. In addition to its stunning coastal view, the beach is also known for its culinary tourism. According to the study has been conducted by emphasized that Depok Beach has many valuable assets for development, such as a large pool of human resources, easy accessibility, good mobile connectivity, a bustling fish auction, and a windmill that provides electricity for the local community. Moreover, the beach offers attractive events and sights such as eye-catching views, fish landings, fish auctions, fish shops, variation fish culinary, kite festivals, and souvenirs [1]. Depok Beach also hosts an annual festival that attracts more tourists. The local community, including fishermen and merchants, has managed these potential resources, which have become their primary source of income.

3.2. Depok Beach development

The original inhabitants of Depok Beach were slum settlers who worked as farmers on sandy land. However, in 1997, fishermen from Cilacap started anchoring on the coast of Depok with abundant marine catches. It sparked interest among the local community to switch professions to become fishermen due to the perceived profitability and abundance of natural resources. The increase in the number of fishermen positively influences the amount of fish caught. It led the local community to take the initiative and build a Fish Landing Base (PPI), followed by a Fish Auction Place (TPI). Gradually, the auction place became a place for fishermen to sell their catch from the Depok coast and those from other areas. Therefore, the coastal area gained recognition as a fishing village.

As the number of tourists increased, the village became a tourist destination, capitalizing on its abundant marine resources and the local community's effort to develop this area. This local community established stalls selling processed fish and other seafood, which tend to be purchased directly from TPI. The development of tourist spots improves the infrastructure and brings more street vendors and stalls to the area. In addition to beautiful beach views, tourists can enjoy various attractions, including fish landings, fish auctions, fish sales, fish-based culinary delights, light aircraft attractions, kite festivals, and souvenir sales. This development has improved the local economy and made the community better.

Public awareness is one of the essential elements in the improvement of Depok Beach. Another element is the formation of the Mina Bahari 45 Tourism Cooperative, Depok, which helps regulate the area's management, particularly regarding infrastructure. Depok Beach can accommodate 5,000 to 10,000 visitors per day on a 1-ha land area with parking for 200 to 300 cars. The cooperative management plans to establish an integrated fish management unit,

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focusing on culinary offerings, construct a swimming pool, meeting rooms, repair stalls, and a mosque to provide visitor facilities.

3.3. Depok Beach management

Since 2000, the Mina Bahari 45 Cooperative has managed the Depok coast. The cooperative has a leadership structure of a general chairman, two chairpersons, two secretaries, two treasurers, cooperative managers, and supervisors consisting of the director and the members. Formed for the benefit of its members, the cooperative operates on a system of "for members and by members." It involves 875 members: fish traders, culinary stalls, street vendors, and fishermen. The cooperative follows regulations agreed upon by all members in carrying out its functions.

Generally, the Mina Bahari 45 Tourism Cooperative in Depok oversees culinary stalls, street vendors, fish traders, fishermen, and various business sectors on Depok Beach. The cooperative also has a manager responsible for tourism sustainability planning based on a macro and accrual view. Based on the cooperative regulations, each existing business unit is responsible for maintaining harmony between its members and management. This group has the flexibility to manage each unit's management considering that the cooperative's finances could be more supportive.

In addition to the cooperative as the management, an organization exists in the coastal tourist area of Depok, namely Tourism Awareness Group (*Kelompok Sadar Wisata, Pokdarwis*). Pokdarwis plays an essential role in tourism development and acts as an environmental supervisor, overseeing social activities and fishing catches to protect scarce marine resources. The Pokdarwis in Depok Beach also keep buskers and beggars out of the area to maintain tourists' comfort.

Several related agencies, such as the Tourism Office and the Marine and Fisheries Agency, support cooperatives managing Depok Beach. These agencies serve as mentors for each business group in the Depok coastal area, advising them on taking advantage of opportunities to improve the welfare of the community. The Cooperative Service oversees the Mina Bahari 45 Tourism Cooperative in Depok, while the Tourism Office supervises the cooperative manager and provides cleaning staff. Meanwhile, the Department of Marine Affairs and Fisheries oversees the fish auction business unit.

The Tourism Office is fully responsible for collecting fees at Depok Beach. The parking fees will be deposited in the cooperative's treasury and used for infrastructure development. About 50% of parking revenue is earmarked for infrastructure development, while the remaining amount is used for the welfare of members. Meanwhile, retribution income is the sole responsibility of the Tourism Office—the cooperative needs to do so through the local village when it wishes to apply for funds.

3.4. Causal loop diagram of Depok Beach management

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The development of Depok Beach as a tourist attraction (ODTW) faces many problems, particularly in terms of sustainability. Sustainability is critical due to the overuse of natural resources [6]. The interdependency between the social system, economy, and environment and their impacts on tourism sustainability must also be considered [10]. These factors make the development strategy for Depok Beach a tourist attraction complex.

The preliminary model of Depok Beach management is depicted in a causal loop diagram. Figure 1 shows the Depok Beach tourism management model, incorporating social, economic, and environmental aspects.

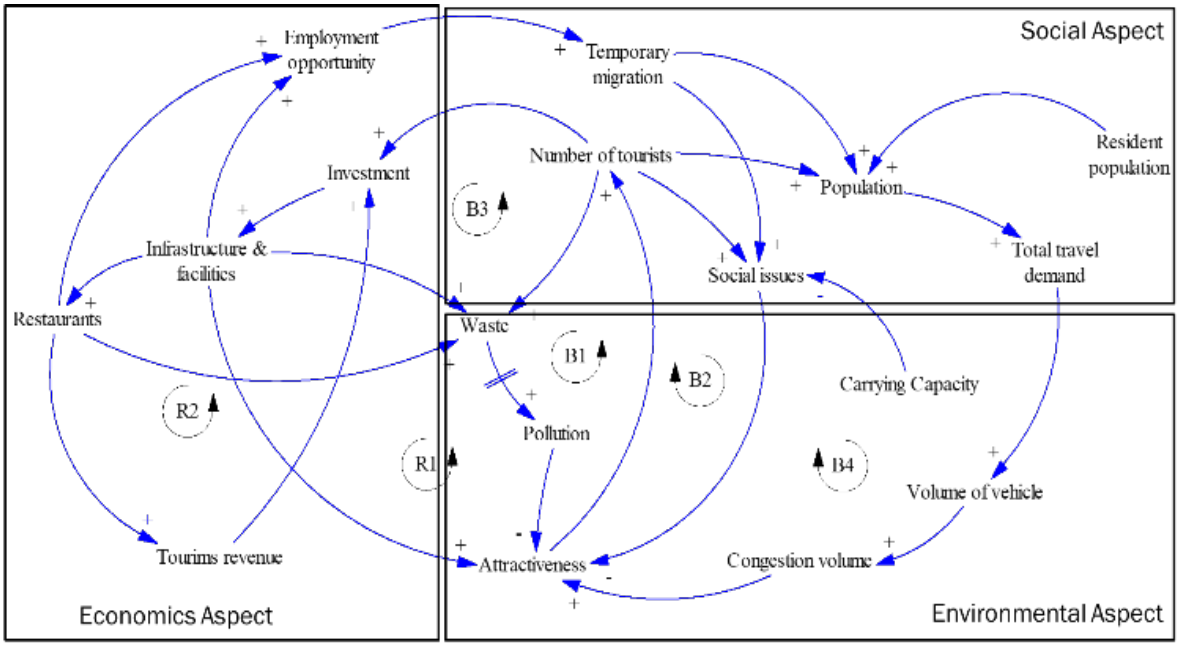

Figure 1. Causal loop diagram of Depok Beach development [29].

Social sustainability focuses on preserving cultural and local identity, honoring cultural, racial, and religious diversity, preserving social values and norms, and promoting equity and human rights [30]. Several studies showed that life quality has improved since Depok Beach became a tourist attraction. The development of the coastal zone affects social aspects such as nutrition, health, and education through increased consumption of seafood, availability of healthcare, and local participation in education [31].

This study showed that Depok Beach positively affects the economy by creating business and job opportunities for the local community, which helps reduce poverty rates [31]. Residents in the area work in various industries, such as fish trading and processing, fishing, selling decorative items, kite crafting, and car rental services. It is supported by [7], which explained that Depok Beach has already proven to positively impact the local economy by increasing tourist activity and attendance.

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Ecological sustainability aims to preserve environmental quality for economic activity and quality of life. It includes protecting nature, decreasing emissions and pollution, and controlling resource use [30]. Waste management at Depok Beach is inadequate and harms the surrounding water and air. Tourists, fishers, marine debris, and local communities generate waste. Furthermore, the increasing rate of tourist visitation only exacerbates the issue. Currently, efforts to maintain coastal cleanliness and involve locals need to be improved, hindering the development of Depok Beach as a tourist attraction [1,3,7].

3.5. Simulation of behaviour of Depok Beach management system

Stock and flow diagrams are a tool for predicting future coastal management systems in Depok. They are based on a previous qualitative model and allow for simulations. Figure 2 shows the stock and flow diagrams in this study.

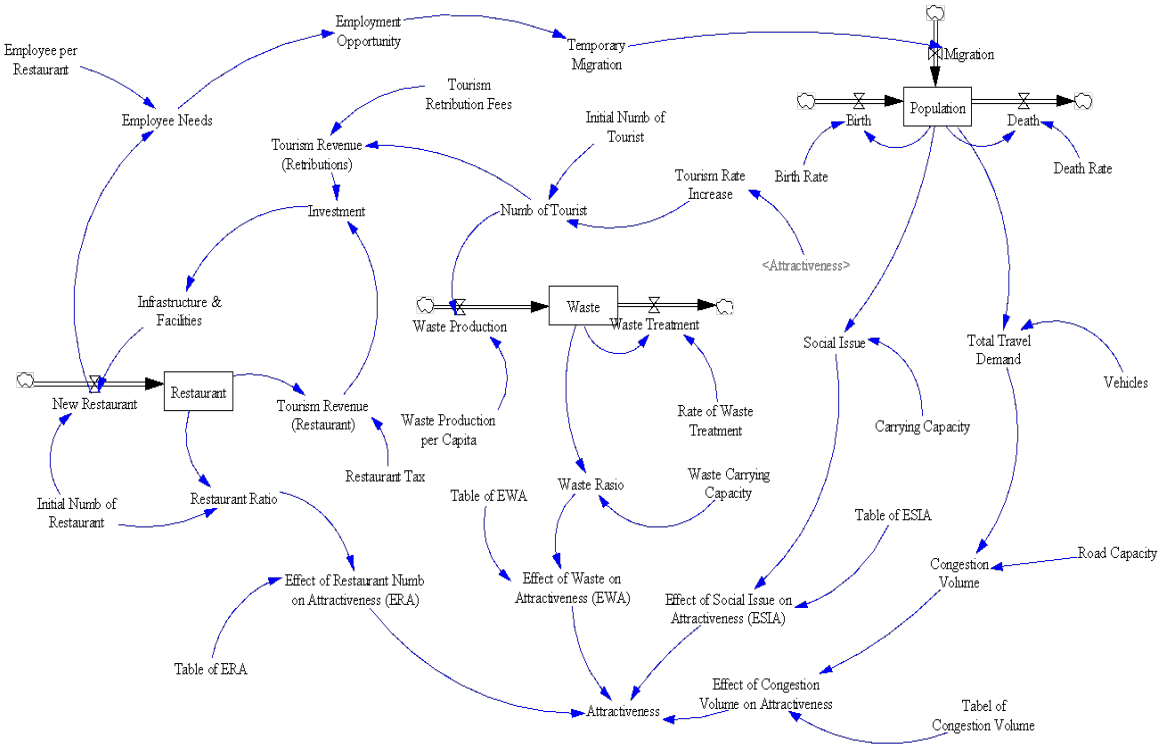

Figure 2. Stock and flow diagram of Depok Beach development.

This study uses stock and flow diagrams to analyse system behaviour, focusing on tourist numbers. Tourist numbers serve as a critical indicator of the development of a tourist destination, which is characterized by growing interest. Figure 3 shows the simulation results.

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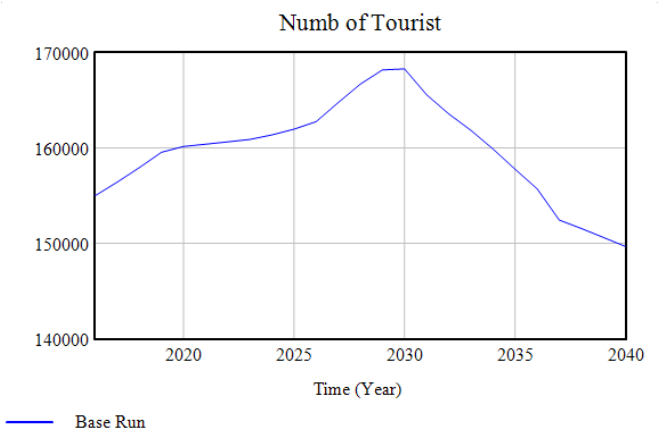

Figure 3. Projection of the number of tourists.

Tourism at Depok Beach is expected to continue growing based on projected visitor numbers. However, a decrease in visitor numbers is expected in 2030, followed by an increase from 2030 to 2040. A decline in visitor numbers at Depok Beach can be caused by factors that affect the attractiveness of tourist objects. Various positive or negative factors influence the development of tourist attractions. Figure 4 shows the variables that directly affect the tourist attraction of Depok Beach.

In the early period, the tourist attraction of Depok Beach grew due to an increase in the number of restaurants, which are the main attraction. The restaurant increase continues until 2030, but this number will later stabilize. It can occur due to limited land and stagnation in visitor numbers, making it less attractive for entrepreneurs to open new restaurants.

The tourist attraction of Depok Beach can also be influenced by increasing waste levels, social issues, and vehicle density. An increase in visitor numbers leads to a rise in residents near the beach. It increases the likelihood of social and environmental problems.

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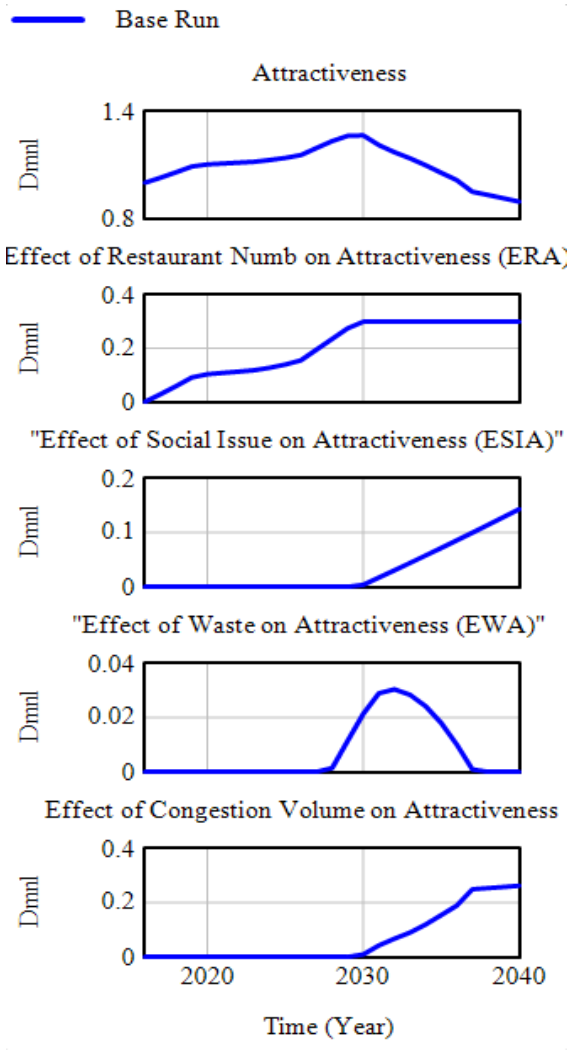

Figure 4. Depok Beach attractiveness graph.

The simulation results showed that waste management is the first problem arising from increased tourist numbers. Increasing tourists can automatically raise the amount of waste around the beach. This condition is followed by issues related to social and high vehicle density. It is essential to address these interrelated factors to ensure the potential growth of Depok Beach.

3.6. Scenario simulation of sustainable Depok Coastal management system

The policy simulation was conducted using several events in managing the Depok coast. Also, the simulation was carried out based on quantitative models and adopted several scenarios, such as increasing waste management capacity and organizations to prevent social conflicts. Figure 5 shows the results of the scenario.

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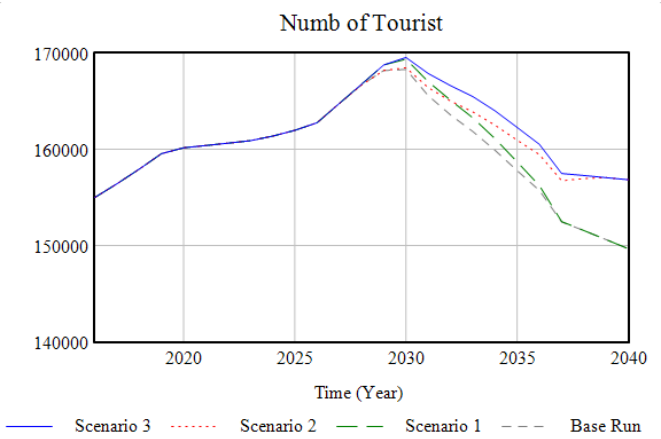

Figure 5. Scenario simulation results on the number of tourists.

The first scenario shows that increasing the capacity of waste management sites on Depok Beach can encourage an increase in the number of tourists. However, improvement in one aspect alone cannot have a significant impact. The decrease in the number of tourists will still occur due to problems with other variables. The second scenario involves implementing a strategy to prevent social conflicts among communities surrounding the Depok coast. This scenario is more effective in reducing the number of tourists. Recently, the number of tourists will prevent a more significant decrease when it still decreases under this scenario.The third scenario involves combining the first two scenarios. These simulation results showed that the implementation of the third scenario is preferable. However, the number of tourists will still decrease in specific years. It shows the need for additional scenarios to develop Depok Beach sustainably.

The policy for the sustainable development of Depok Beach needs to involve various interconnected aspects, including social, economic, environmental, and institutional. Sole interventions in a single aspect will not substantially impact the sustainability of the Depok coast.

4. Conclusions

The potential for the development of Depok Beach includes culinary tourism. Projections show that the visitor numbers are expected to increase until 2030 but will decrease after 2030 due to the low attraction of the beach. Factors such as the number of restaurants, waste management, social problems, and road capacity influence the attraction. Furthermore, the limited capacity of landfills serves as a significant challenge in the development of Depok Beach. Other social problems can hinder the growth of restaurants and the management of the beach when they are not addressed. Moreover, integrated policies are necessary to address and minimize these potential challenges.

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