Research Article

Tidal Flood Mitigation Model Using the Life Cycle Approach (LCA) in Coastal Areas of Pekalongan City

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Abstract.
The government (both central and regional) has addressed the issue of tidal flooding in Pekalongan City through various means. However, tidal floods will continue to pose a threat to Pekalongan City in the future. It is necessary to integrate policy programs and research approaches that adhere to the principles of sustainable development (ecological justice). One of the popular models today is the Life Cycle Approach (LCA). This study aims to 1) develop a tidal flood mitigation model in Pekalongan City using a Life Cycle Approach (LCA), 2) Analyze the advantages and disadvantages of applying a tidal flood mitigation model with a life cycle approach in the coastal area of Pekalongan City. This research is a development research carried out using a Participative Action Research (PRA) approach. Data collection techniques involve triangulation and analyzed using mixed methods. The results of this study indicate that: 1) the tidal flood mitigation model in Pekalongan City with a life cycle approach meets validation standards/criteria, 2) advantages: oriented to long-term solutions, more effective in overcoming tidal flood problems, can reduce maintenance costs, encourage involvement community, can improve environmental quality. Disadvantages of LCA: requires more time and cost, lack of flexibility, difficult decision-making, inability to guarantee project success, and lack of community participation, 3) Solutions to overcome weaknesses or disadvantages in implementing a tidal flood mitigation model with a life cycle approach in the coastal area of Pekalongan City, namely: a) speeding up the planning process, b) enhancing flexibility, c) improving transparency of decision-making, d) conducting simulations and trials, and e) increasing public participation.

Keywords: mitigation model, tidal flooding, life cycle approach (LCA)

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1. INTRODUCTION

Tidal floods in Pekalongan City that have occurred decades ago, since 2012, 2014, 2015, 2016 and 2017 have and will cost a lot of money with social losses [1], [2], [3], the economy [4] reaches 4 (four) trillion and will be even greater until 2035 and the impact on public health is quite large [5], [6], [7], [8].

Several factors causing tidal flooding can be divided into two, namely natural and human factors. First, natural factors consist of: 1) land subsidence that has occurred

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significantly [9], [10], [11], [12], [13], [14]; 2) Tides due to gravity [15], [16]; 3) rainfall, wind and climate change [11], [17], [18], [19], [20], 4) global warming [21], [22], [23] 5) siltation and river sedimentation [24], [25], [26]. Second, the human factor. Greed and low public awareness of the low environment are indicated by human behavior, such as 1) deforestation of mangrove forests [27], [28], [29], [30], [31], 2) land conversion [32], [33], [34], 3) Damaged or non-functioning protective structures such as embankments [35], 5) population density in coastal areas [36], [37], [38], [39].

The damage to coastal ecosystems is further compounded by the behavior of the batik industry (factory and home industry) which dumps waste directly into the river. The batik business in Pekalongan City is estimated to produce at least 5 million liters of waste every day, according to the Pekalongan City Environment Agency (DLH). Only 45% of all waste generated by the batik industry that can be accommodated in the Pekalongan City Wastewater Treatment Plant (IPAL); the rest is simply thrown into the river [40]. As a result, the quality of the environment where people live decreases and increases organic content such as COD, BOD, TSS and pH, which can cause the death of aquatic organisms [41] and the batik waste also causes rivers to experience siltation and narrowing [42].

The problem of tidal floods with very complex waste management, especially in terms of public awareness of batik business actors and government policies and very weak enforcement of environmental laws, has been proven to have played a major role in the occurrence of tidal floods in Pekalongan City. Because apart from dumping waste directly into the river, business owners also exploit groundwater (bore wells) excessively, and this has also accelerated the process of land subsidence in Pekalongan City [24]. Various efforts have been made by the Central Government, Central Java Provincial Government, Pekalongan City Government, non-governmental organizations, academics, and other stakeholders [43]. However, tidal floods in the future will continue to threaten Pekalongan City. Integration of policy programs and research approaches is needed that adheres to the principles of sustainable development (ecological justice). One of the currently popular models is the Life Cycle Approach (LCA).

Models with a life cycle approach have been widely applied by previous researchers from various disciplines, such as: Technology and information [44], Waters and Coastal Communities [45], Computer/software [46], [47], Mechanical engineering [48], [49], Economics/management [50], [51], [52], Mathematics [53], [54], Environment [55], Chemical Engineering [56]. Electricity [57]. However, there is no research that explains in detail the roles and functions of stakeholders in the tidal flood mitigation agenda. Therefore, it is necessary to carry out an in-depth study of tidal flood mitigation modeling that occurs in Pekalongan City using a Life Cycle Approach.

2. METHOD

This research is a development research that is developing a model or prototype of tidal flood disaster mitigation with a life cycle approach (LCA). The steps taken in this study followed the development research procedure as written by [58]: (1) Potential and problems, (2) Data collection, (3) Model design, (4) Design validation, (5) Design revision, (6) Model trial, (7) Model revision, (8) Model trial, (9) Model revision and (10) Model application in bulk.

Data collection techniques and tools used in this study were observation guides, interviews, questionnaires and documentation (triangulation). The questions were based on the theories and concepts described in the previous section. The data collected is related to the development components that will be carried out using the LCA model, namely: 1) involvement, relevance, and empowerment of beneficiaries; 2) accountability; 3) impact, innovation and evidence; 4) value for money; 5) scalability and replication; 6) advocacy, campaigns, and social change [59].

Data analysis used a mixed method, namely descriptive statistical analysis and qualitative analysis with interactive analysis. Descriptive statistical analysis is used to describe stakeholder participation in disaster mitigation programs/policies according to the design model. Research data converting with conversion guidelines as follows [60]. The criteria measured as a model validation component are: 1) model effectiveness, 2) sustainability, 3) cost efficiency, 4) model integration with the surrounding area, 5) safety, and 6) model flexibility.

Table 1: Guidelines for Converting the Effectiveness of the Tidal Flood Mitigation Model Using a Life Cycle Approach.

Criteria	Qualification
> (Mi + 1,5SDi)	Very Good/Fit/High/Effective
(Mi + 0,5SDi) s/d (Mi + 1,5SDi)	Good/Fit/High/Effective
(Mi - 0,5SDi) s/d (Mi + 0,5SDi)	Moderate/Enough
(Mi - 1,5SDi) s/d (Mi - 0,5SDi)	Poor/Inappropriate/Low/Ineffective
< (Mi - 1,5SDi)	Very Poor/Very Inappropriate/Very Low/Very Ineffective.

Description:

Mi = Ideal Mean

= ½ (ideal maximum score + ideal minimum score)

Sdi = ideal standard deviation

= 1/6 (ideal maximum score - ideal minimum score)

Furthermore, interactive qualitative analysis consists of four components, namely: 1) data collection, 2) data condensation, 3) displaying data, 4) drawing conclusions: description or verification [61].

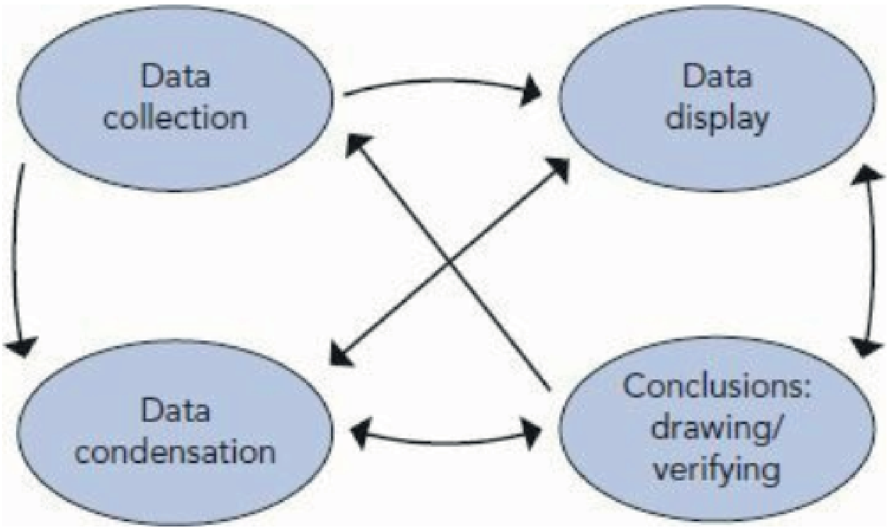

Figure 1: Qualitative Data Analysis with Interactive Models.

Description:

Data Collection: done by triangulation (interviews, observations, and documentation)

Data Condensation: refers to the process of selecting, focusing, simplifying, abstracting, and/or transforming the data that appears in the complete corpus (body) of written field notes, interview transcripts, documents, and other empirical materials.

Data Display: a well-organized and dense collection of data that enables decision-making and action. Views in everyday life that can help researchers understand what is going on and take action based on that understanding (either further analysis or action). This is related to information from informants and the practices they carry out on a daily basis in carrying out their duties and functions as community servants in the village.

Conclusions, Drawing/Verifying**:** When conducting data analysis, the researcher re-examines the provisional conclusions obtained both general and specific descriptions of the research problem. Field data and temporary conclusions were then cross-checked or verified based on new findings or follow-up findings during the research, efforts were made to replicate the findings in other data sets. The meaning that emerges from the data must be checked for reasonableness, robustness, and confirmability

3. RESULST AND DISCUSSION

3.1. Potential Problems

The fundamental principle of the model developed in this study is to examine the proper makeup of social vulnerability when interacting with risk. The results of this study focused on 4 (four) potential problems in mitigating tidal floods that occurred in Pekalongan City, namely: 1) underlying causes, 2) dynamic pressure, and 3) dangerous situations and 4) mangrove conservation. When a crisis hits, everyone pays attention to the hazardous conditions that expose individuals to risk, such as exposure to risk areas, inadequate infrastructure, and lack of preparation. Unsafe situations caused by dynamic stresses generated by root causes that are far in the background (before disaster occurs). Dynamic stresses are further investigated, followed by imminent hazardous situations, and finally the underlying causes.

The following is a risky situation that occurred in the coastal area of Pekalongan city or at the research location which was the underlying cause:

Population exposed in risk areas, hazardous areas, densely populated areas and unprotected areas.

Poor physical infrastructure against extreme hazards such as embankments, sea walls, scarcity of clean water, check dams, slope protection and unadapted residential buildings.

Lack of infiltration and storage facilities and control of urban development.

Weak houses and buildings (not adaptive to the environment) and lack of enforcement of building regulations (there is no PERDA or Mayor's Regulation regarding structures and building materials suitable for coastal areas).

Poor early warning and evacuation system.

Poor monitoring system or lack of availability of hazard maps and their use by the community.

Lack of community preparedness, education, training, disaster literacy, and others.

Weak emergency response and rescue systems, poor recovery assistance programs.

Second, potential problems with dynamic stress include the following processes and activities.

Population increase, rapid urbanization, urban concentration, depopulation and aging and other demographic processes.

Poor migration/settlement controls to risk areas.

Industrialization (batik factory or home industry), deforestation of mangrove forests or coastal plant ecosystems, pumping of groundwater, disposal of batik waste directly into rivers and other developments that are not specifically regulated.

Lack of institutional arrangements for coordination across sectors, disciplines, government and society of various levels for disaster management.

Lack of laws and/or regulations (PERDA and/or PERWAL) and lack of law enforcement.

Poor investment in disaster prevention and mitigation infrastructure, science and technology, education, observation and forecasting (prediction).

Lack of integrated management of land and water resources.

The batik industry (manufacturing or home industry) and the construction of multi-storey buildings (hotels, colleges and others), are not at all bad things to do or maintain, but it is important to strike a careful balance in terms of disaster risk. These imbalances are often due to more underlying causes, i.e. underlying factors that tend to shape the processes and actions of these imbalances that constrain communities or governments to take effective disaster risk reduction measures, such as large numbers of people choosing to stay in their house even though it was already flooded. They (the community) are reluctant to be evacuated to the flats that have been provided by the government.

Third, potential problems in economic, political & socio-cultural conditions, such as:

Inequalities in economic opportunity (poverty, segregation between rich and poor, fishermen and batik makers, link between disaster risk and poverty, inefficient use of aid).

Lack of political will (imbalance in prioritization between economic opportunity and disaster risk reduction).

Lack of local community capacity (low behavioural discipline, low environmental awareness, lack of leadership, disaster literacy).

Tidal Flood Mitigation Modelling with Life Cycle Approach (LCA)

The discussion of the results of this study is divided based on the research objectives, namely: 1) tidal flood mitigation modeling using the Life Cycle Approach approach, 2)

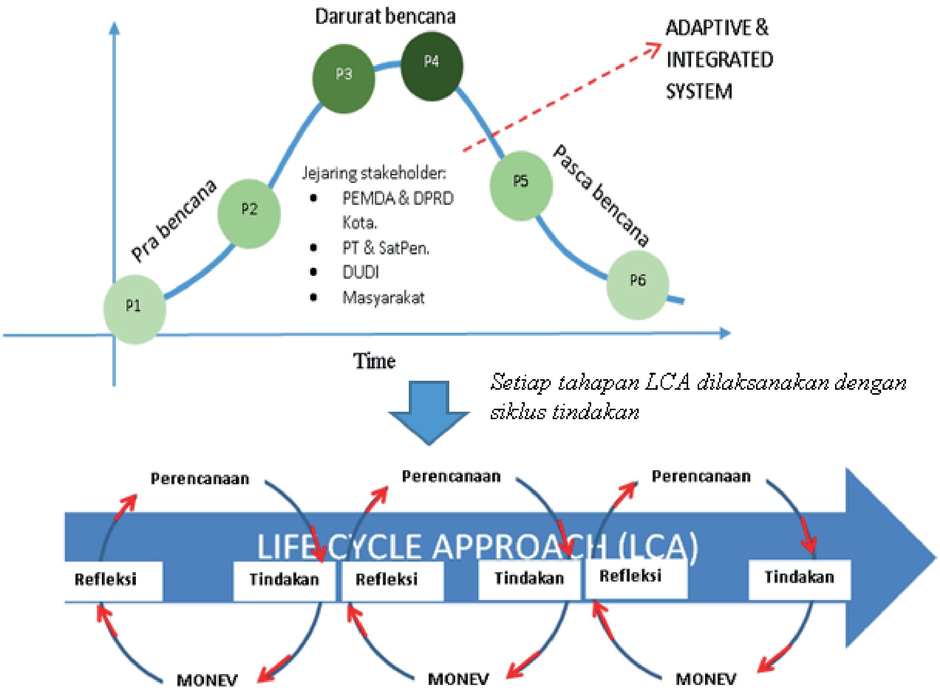

Figure 2: Revision of Design/Model of Tidal Flood Mitigation with Life Cycle Approach.

Strengths and Weaknesses of the Life Cycle Approach Approach, and 3) Solutions to the weaknesses of the tidal flood mitigation model using the Life Cycle Approach approach.

3.2. Model Validation

This research has just reached the stage of model validation with components measuring/assessing on the aspects of: Model effectiveness, Sustainability, Cost Efficiency, Integration with Surrounding Areas, Security, and Model flexibility.

3.3. Model Effectiveness

The tidal flood mitigation model with a life cycle approach is considered quite effective in dealing with tidal flood problems. The life cycle approach is an approach that takes into account environmental impacts throughout the product life cycle, from production to disposal. In the context of tidal flood mitigation, the life cycle approach can help identify the sources of tidal flooding problems, both in terms of production, use and disposal of waste that can affect the quality of the environment.

The tidal flood mitigation model with a life cycle approach will be effective if it is carried out in an integrated manner, from planning to the stop phase, so as to minimize the environmental impact caused by tidal floods. However, the success of the life cycle approach in tidal flood mitigation is highly dependent on public awareness to adopt an environmentally friendly lifestyle and cooperation between the government, the community, universities, educational units, the business world and the industrial world, as well as private institutions (foundations/NGOs).

3.4. Model Sustainability

The level of sustainability of the tidal flood mitigation model with a life cycle approach is very dependent on the ability of the system to maintain its functions and benefits in a sustainable manner. There are several factors that can affect the sustainability of the tidal flood mitigation model using the life cycle approach, among others:

Effectiveness: The level of sustainability of the tidal flood mitigation model is greatly influenced by the effectiveness of the technology and strategies used in overcoming the tidal flood problem. Technologies and strategies that are effective in overcoming tidal floods will be better able to maintain the benefits and functions of tidal flood mitigation in a sustainable manner.

Community Participation: The level of community participation in the tidal flood mitigation process greatly influences the sustainability of the tidal flood mitigation model. The community must be actively involved in the process of planning, implementing and maintaining the tidal flood mitigation system in order to maintain the sustainability of the system.

Maintenance: A good level of maintenance is essential in maintaining the sustainability of the tidal flood mitigation model. Regular maintenance will ensure that the tidal flood mitigation system continues to function properly and minimizes the risk of damage.

Availability of Resources: Availability of resources such as funds, labor, and raw materials is very important in maintaining the sustainability of the tidal flood mitigation model. The availability of adequate resources will ensure that the tidal flood mitigation system can be operated and maintained properly.

Overall, the sustainability of the tidal flood mitigation model with a life cycle approach can be achieved by taking into account the factors mentioned above. Therefore, there is a need for good cooperation and coordination between the government, the community and the private sector to create a sustainable tidal flood mitigation system..

3.5. Cost Efficiency

The efficiency of the tidal flood mitigation model with a life cycle approach can be measured from various aspects such as:

Cost Efficiency: The use of a life cycle approach in the tidal flood mitigation model can help in minimizing the overall costs incurred. The life cycle approach can assist in selecting the most effective and efficient technologies and strategies in overcoming tidal floods and sustaining the benefits in a sustainable manner.

Energy Efficiency: Selection of the right tidal flood mitigation technology and strategy can help reduce energy consumption and greenhouse gas emissions. The life cycle approach can help in selecting technologies that are more environmentally friendly and have lower energy consumption levels.

Efficient Use of Resources: Efficient use of resources is very important in maintaining the sustainability of the tidal flood mitigation model. By using a life cycle approach, it can help in selecting technologies and strategies that are more efficient in the use of resources and reduce the excessive use of resources.

Time Efficiency: Application of a tidal flood mitigation model with a life cycle approach can help save time and reduce the time required for system planning, implementation and maintenance.

The use of a life cycle approach in a tidal flood mitigation model can assist in increasing the efficiency of resource use, reducing costs, energy consumption, and greenhouse gas emissions, as well as saving time. Therefore, the life cycle approach can be an effective and efficient alternative in overcoming tidal floods.

3.6. Integration with the Surrounding Area

The life cycle approach in the tidal flood mitigation model can help improve integration with the surrounding area in the following ways:

Involve stakeholders: The life cycle approach allows involving various stakeholders in the tidal flood mitigation process, including local communities, government agencies, and the private sector. In this process, stakeholders can provide valuable input to design and implement a more effective and integrated tidal flood mitigation system with the surrounding area.

Using local resources: The life cycle approach also allows utilization of local resources for tidal flood mitigation systems, such as local building materials, and local labour. This can help strengthen integration with the surrounding area because the use of local resources can increase the dependency between the tidal flood mitigation system and the surrounding area.

Integrated water management: A life cycle approach can assist in strengthening integration with surrounding areas through integrated water management. A tidal flood mitigation system can be designed to take advantage of local water resources such as rainwater and surface water. In this way, the tidal flood mitigation system can improve integration with the surrounding area in water management.

Development of sustainable urban planning: The life cycle approach can help in developing sustainable urban planning and considering tidal flood mitigation as an important element of urban planning. In this case, the tidal flood mitigation system can become part of an integrated urban planning and assist in achieving long-term sustainability goals.

The life cycle approach in the tidal flood mitigation model can help improve integration with the surrounding area, through involving stakeholders, using local resources, integrated water management, and developing sustainable urban planning. This can help create an effective and sustainable tidal flood mitigation system for the future.

3.7. Model Security

The life cycle approach in the tidal flood mitigation model can help improve the level of security in the following ways:

Improving the understanding of tidal flood risk: In the life cycle approach, the risk of tidal floods can be analyzed in more detail and comprehensively, thus enabling the development of a more effective tidal flood mitigation system. Better tidal flood risk analysis can help identify the most vulnerable areas and determine the most appropriate mitigation strategy to reduce the risk.

Determine the best mitigation option: The life cycle approach allows comparisons between various mitigation options, including the security associated with those options. In selecting the best mitigation option, the life cycle approach considers environmental, social, economic and technical aspects, so that the selected option can offer an optimal level of security.

Appropriate use of technology: The life cycle approach also allows identification of the most appropriate mitigation technology to reduce the risk of tidal flooding. The right mitigation technology can help increase the security level of tidal flood mitigation systems, including monitoring technology, decision-making systems, and information and communication technology that assist in dealing with tidal flood threats.

System maintenance and management: The life cycle approach also helps in the maintenance and management of tidal flood mitigation systems. Properly designed and properly implemented systems can help ensure that they remain safe and effective over their lifetime.

The life cycle approach in the tidal flood mitigation model can help increase the level of safety by increasing the understanding of tidal flood risk, choosing the right mitigation options, using the right technology, and system maintenance and management..

3.8. Model Flexibility

The life cycle approach can provide a high degree of flexibility in the tidal flood mitigation model because it involves regular evaluation and updating stages. Some examples of the level of flexibility that can be achieved using the life cycle approach in the tidal flood mitigation model are as follows:

Selection of suitable technology: In the planning stage, a life cycle approach can assist in selecting the most suitable and effective technology to mitigate tidal floods. In the update stage, a life cycle approach can also assist in selecting newer and more effective technologies that may become available.

System upgrade: In the renewal stage, the life cycle approach can assist in upgrading the existing tidal flood mitigation system. This can be done by evaluating system performance and updating the technology used to optimize system performance.

Adaptation to climate change: The life cycle approach can assist in adapting the tidal flood mitigation system to the climate change that is occurring. In the evaluation phase, changes in rainfall patterns and water levels can be evaluated and the tidal flood mitigation system can be adapted to these conditions.

Maintenance and repair: A life cycle approach can assist in maintaining and improving existing tidal flood mitigation systems. In the maintenance phase, routine maintenance and repair of the system can be performed to ensure optimal performance and extend system life

The life cycle approach in the tidal flood mitigation model can thus provide a high level of flexibility, by allowing changes and improvements to the tidal flood mitigation system as needed. This can help in ensuring that the tidal flood mitigation system can function optimally for a long period of time.

Advantages and Disanvantages of Tidal Flood Mitigation Model with Life Cycle Approach (LCA)

3.9. The Advantages

Some of the advantages of the tidal flood mitigation model with a life cycle approach are:

Oriented to long-term solutions: The tidal flood mitigation model with a life cycle approach emphasizes long-term and sustainable solutions, so as to reduce the risk of tidal flooding in a longer period of time.

More effective in overcoming tidal flood problems: The tidal flood mitigation model with a life cycle approach considers the entire life cycle of a project, from planning, design, construction, operation, and maintenance. This allows for a more effective and integrated solution to the tidal flood problem.

Can reduce maintenance costs: The tidal flood mitigation model with a life cycle approach can reduce maintenance costs over a longer period of time, because it considers maintenance as part of the design and development process.

Encouraging community involvement: The tidal flood mitigation model with a life cycle approach can encourage community involvement in the project planning and implementation process, thereby increasing community awareness and participation in reducing the risk of tidal flooding.

Can improve environmental quality: The tidal flood mitigation model with a life cycle approach can consider the environmental impact of the project and develop environmentally friendly solutions, so as to improve the quality of the environment around the project area.

3.10. Disadvantages

Some of the disadvantages of the tidal flood mitigation model with a life cycle approach are:

Time consuming and costly: The complete life cycle process from planning to maintenance can be time consuming and costly, especially during the initial planning and design stages.

Lack of flexibility: The tidal flood mitigation model with a life cycle approach tends to have a design that is more rigid and less flexible to change or modify in a short period of time, thereby limiting the ability to adapt to changes in environmental conditions or community needs.

Difficult in decision making: A more detailed and integrated planning and evaluation process can make decision making more difficult and complicated, especially in terms of setting priorities or budget allocation for tidal flood mitigation projects.

Cannot guarantee project success: A tidal flood mitigation model using a life cycle approach may not be able to guarantee overall project success, especially if there are unpredictable external factors, such as extreme weather conditions or natural disasters.

Lack of community participation: A process that is too complicated and lengthy can make the community less interested or have difficulty understanding the tidal flood mitigation project, thereby reducing community participation and support for the project.

Solutions to Overcome Disadvantages in the Tidal Flood Mitigation Model with a Life Cycle Approach

Some solutions to overcome the weaknesses of the Tidal Flood Mitigation Model with a Life Cycle Approach are:

Speeding up the planning process: In order not to take too long in the planning process, more sophisticated technologies such as 3D design software and hydrological analysis can be used which can speed up the planning process and reduce costs.

Increasing flexibility: In designing a tidal flood mitigation project with a life cycle approach, it is necessary to consider providing flexibility in the project design so that it can be changed or modified in a short period of time, especially at the initial design stage.

Increase decision-making transparency: To overcome difficulties in decision-making, it is necessary to increase decision-making transparency, especially in terms of prioritizing or budget allocation for tidal flood mitigation projects, so that people can understand the decision-making process.

Conducting simulations and trials: To ensure project success, it is necessary to carry out simulations and trials in the laboratory or in the field before the project is carried out en masse, so as to identify potential problems or failures in the project.

Increasing community participation: In order for the community to be more interested in and involved in tidal flood mitigation projects, it is necessary to increase community participation in the project planning and implementation process, such as involving the community in surveys or public consultations and providing easy-to-understand information about the project

4. CONCLUSION

Based on the results and discussion of the research as previously described, it can be concluded that:

The tidal flood mitigation model in Pekalongan City with the Life Cycle Approach (LCA) is carried out with the stages of the life cycle, namely: a) the stages of emergence or birth (birth) of tidal floods, 2) growth/development (growth) of disasters, 3) the disaster maturity stage, 4) the disaster saturation stage, 5) the decline stage, and 6) the stop/death stage and/or recycle. The mitigation model with this approach has met validation standards/criteria, including: a) model effectiveness, 2) sustainability, 3) cost efficiency, 4) integration with the surrounding area, 5) security, and 6) model flexibility.

The advantages and disadvantages of applying the tidal flood mitigation model with a life cycle approach in the coastal area of Pekalongan City, namely:

4.1. Advantages

Oriented to long-term solutions.

More effective in dealing with tidal flood problems.

Can reduce maintenance costs.

Encourage community involvement.

Can improve environmental quality.

4.2. Disadvantages

Requires more time and money

Lack of flexibility.

Difficult in decision making.

Cannot guarantee project success.

Lack of community participation

Solutions that can be made to overcome the weaknesses/advantages of applying the tidal flood mitigation model with a life cycle approach in the coastal area of Pekalongan City, namely: a) speeding up the planning process, b) increasing flexibility, c) increasing transparency of decision making, d) conducting simulations and trials, and e) increasing community participation.

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