Pavement Rehabilitation & Reconstruction Policy for Optimization of Life-Cycle Costs and Trauma Healing Post-Disaster

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Abstract-Natural disasters that cause damage to road infrastructure can foster a sense of trauma. The stages of rehabilitation and reconstruction must be carried out as soon as possible as a trauma healing step for the community. However, the process is constrained by budget constraints, so an approach to optimization is needed to minimize costs while still solving problems. This study was developed by not only minimizing life cycle cost with road performance index parameters but also incorporating trauma healing goals. The research method used is the LCCA dan index of road performance and is related to the level of trauma healing of the community. The data used are RR-01 and RR-02 Project in Palu. This study will then try to redefine disaster as a continuation of various phases of mutual impact, thus it is necessary to understand these phases by providing interventions at various stages. The results of the study show that there is an optimization between the cost and level of trauma healing achievement when establishing a series of rehabilitation and reconstruction options.

Keywords: Rehabilitation, Reconstruction, Disaster, Optimization.

Introduction

Disasters consist of natural and non-natural disasters such as floods, droughts, hurricanes, landslides, earthquakes, tsunamis, communal riots, armed conflicts, fires, volcanic eruptions and epidemics, and industrial disasters. Natural disasters occur every day throughout the world and affect human life and development. To respond to the various types of natural disasters, proper disaster management techniques and methods are needed through understanding the nature of disasters, their phases and their associated impacts [1]. The responsibility of disaster management is the joint responsibility of all stakeholders, namely the government, the community, NGOs and the private sector.

The earthquake that occurred on September 28, 2018, in Palu-Indonesia was quite shocking to all quarters because the earthquake was accompanied by tsunami waves and liquefaction with thousands of lives. The effect of the earthquake was quite large because the epicenter was not too deep, and the frequency of the earthquake was quite intense. The magnitude of the disaster is recorded regarding the level of vulnerability of the affected population. The earthquake in Palu-Indonesia caused more than 100,000 people to be affected. Shortly after the disaster happened, all related parties tried to do disaster management through post-disaster management.

Palu, Sigi, and Donggala had the biggest influence when the earthquake occurred, apart from the quite high intensity of the earthquake it was also influenced by the presence of a hammer-koro fault that bisected the two areas of the city. This fault is an active fault that extends from central Sulawesi to the Karimata strait [2]. In different literature, it is estimated that this fault moves actively and dynamically with a shift of 41-45 mm/year [3]. Shortly after a series of earthquakes occurred, it was topped by one earthquake with the highest scale then followed by the occurrence of the tsunami and Liquefaction. The tsunami destroyed various infrastructure around the Palu Bay coast, including transportation infrastructure. At the same time, liquefaction also occurred in 4 (four) areas with the greatest influence of liquefaction, namely Petobo, Balaroa, Jono Oge and Sibalaya.

The Palu earthquake, tsunami, and liquefaction have caused massive damage to the entire infrastructure, including roads and accessories. Very many roads have lost their functions or at least a decline in the level of road performance. Not only national roads were affected, but including local roads, district roads up to provincial roads experienced the same thing. When the conditions began to gradually control, the community still left a sense of trauma when they see the remaining infrastructure, especially road conditions and completeness. The sense of trauma is very disturbing residents when they see traces of damage that occurred when the natural disaster occurred. So, it is necessary to immediately do rehabilitation & reconstruction of road damage that occurs. However, the

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availability of the budget is still limited although there are some assistance and foreign loans offered, of course, the government must still pay attention to the efficiency of the use of the budget. Budget constraints, trauma healing, and financing are constraints that must be found for a solution. This study describes the relationship between these parameters.

Disaster Management

Disaster management should not be seen separately but consists of various management phases in dealing with this problem, namely in the form of preparedness, assistance, rehabilitation and reconstruction mitigation. As it is known that the disaster management phase consists of several stages, as can be seen in Figure 1. The stages of the implementation of disaster management are not just one step and continue to stop but are a series from beginning to end which will then repeat. Each stage has different characteristics. Many stakeholders are involved in helping and rehabilitation, but often forget to concentrate on the mitigation and reconstruction stages with a longer duration.

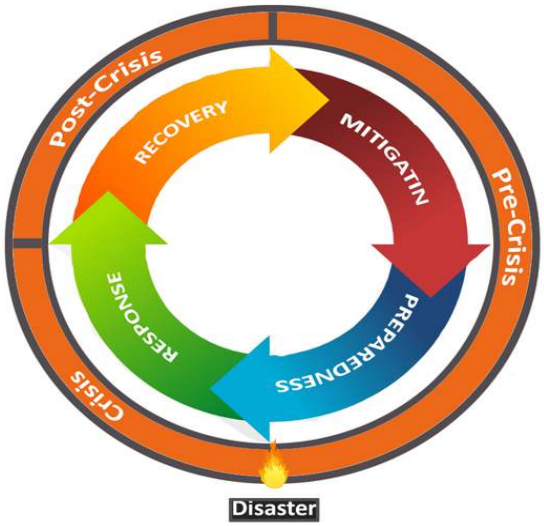

Figure1. Disaster management cycle

The disaster management cycle is the process by which governments, communities, and NGOs plan, implement and control measures to reduce disasters, respond to the consequences of current and subsequent disasters, and take recovery steps after a disaster occurs. The best action at all points in the cycle is on good preparedness, better warning, reducing vulnerability or preventing disaster in the next cycle [4]. In the event of a disaster, effective disaster management is very important to ensure that every step taken does not have an adverse impact in decision making, for example warning to the community, searching and saving victims, providing immediate assistance, damage assessment, ongoing assistance, and immediate recovery or infrastructure development after a disaster.

Rehabilitation

After the crisis management phase is controlled, the next phase is the post-crisis phase in the form of rehabilitation in the weeks and months after the disaster to restore basic services to enable affected populations to return to pre-disaster conditions. Learning from various disaster events around the world and paying attention to the collective experiences of previous disasters around the world, preparation for the rehabilitation phase needs to get better attention. Because a few hours and days after the disaster occurred, the stakeholders must immediately carry out various rehabilitation initiatives ranging from community-based rehabilitation to disability advocacy to quickly focus measures to provide assistance in pre and post medical action among the injured [5]. During the 2018 Palu disaster incident, it was very encouraging to see many NGOs highly dependent on Palu's local human resources, such as health experts to meet the increasing demand for human rehabilitation. But for the rehabilitation of infrastructure to support the return of conditions does not look optimal.

The rehabilitation phase must continue to focus on restoring semi-normal conditions which are still a difficult task because many communities and houses in Palu cannot be accessed by individuals due to the condition of road infrastructure that has not yet recovered, even in several liquefaction locations the road conditions are completely cut off. Most of the buildings are inaccessible and the situation in rural communities far from the center of Palu is much worse. For example, some communities do not have access to roads and the only way to reach them is by

climbing long distances through mountains. Rehabilitation can contribute to solving this problem by increasing function, independence, and participation but in the end, it must be done together with all stakeholders to be sustainable. Rehabilitation professionals must also be involved in the preparation of infrastructure rehabilitation that can be accessed by when Palu starts rebuilding to restore the area to its original state.

Post-disaster infrastructure rehabilitation is a complex problem with several dimensions. governments, NGOs and international organizations have their interests in disaster recovery programs. The form of cooperation and relations between stakeholders must be regulated and built properly without forgetting the participation of the community [6]. In other words, post-disaster rehabilitation and recovery programs must be opportunities to involve the community and serve local needs. Rehabilitation of this infrastructure includes steps that help restore the function of infrastructure in an emergency before further reconstruction will be carried out. The main emphasis is on strengthening active stakeholder coordination by encouraging the participation of affected local potentials in designing and implementing the recovery of these conditions.

Reconstruction

The reconstruction phase is a continuation of the rehabilitation phase. This phase is a step towards rebuilding the condition of the infrastructure that was damaged during the disaster. Reconstruction is not just rebuilding, it is a long-term process and focuses more on restoring the confidence of the affected communities to continue their activities with independence, sustainability, and empowerment. In this reconstruction all parts were touched, so the results were acceptable to all parties. In infrastructure development in areas affected by major disasters, the basic construction of transportation can be done simultaneously to rescue affected communities by opening access as soon as possible [7]. In terms of transportation and logistics, it needs to be done immediately to ensure that the basic needs of the population can be met immediately to provide comfort for the victims.

The decision-making process based on normal stages through feasibility studies and economic analysis to carry out post-disaster reconstruction accordingly may not be applicable because of the demand to act quickly [8]. So that post-disaster road reconstruction requires a different approach. An approach that combines all the limitations and challenges that exist in the post-disaster context, while considering the overall cost of the project, especially the long-term maintenance needs. The optimal financing balance by considering long-term achievements is one of the aspects of accountability in post-disaster financial management [8]. In this context, it is necessary to develop a framework for the reconstruction of post-disaster road infrastructure that is sustainable and can reduce the trauma of the affected victims.

Life-Cycle Costing Analysis

Determining policy by choosing the lowest initial cost cannot guarantee an economic advantage over other options. Low initial costs without considering the consequences that will occur during the life of the planned road infrastructure, usually cause the cost of routine and periodic maintenance required to be greater than the selection of higher initial costs. LCCA is a comprehensive economic evaluation method. LCCA seeks to optimize costs and maximize operational assets over the useful life by trying to identify and calculate all significant costs, using NPV techniques [9]. Furthermore, several definitions of life-cycle costing used today are quite practical compared to other existing methods. Life-cycle costing is the conception and development through operation until the end of its useful life. To make the life-cycle costing procedure more structured and easier to understand, through the basis of a systematic flow like Figure 2. LCCA is very often used to carry out calculations and government investment decisions [10].

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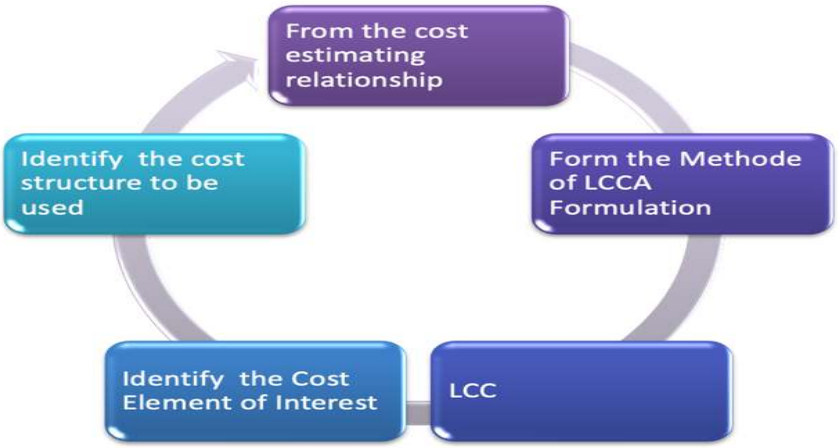

Figure 2. Procedure life-cycle costing

Some literature focuses on life-cycle costing in infrastructure financing research including using the life-cycle costing methodology to identify the total costs in the operation, maintenance and rehabilitation of a construction or construction system over a certain period [11]. Until now LCCA is considered an economic evaluation technique that determines the total costs required in financing infrastructure facilities with certain assumptions. Several LCCA approaches are used to calculate the feasibility and financing models in the road pavement management system. Various financing components by including the time function are included in this LCCA formula.

Trauma Healing Satisfaction

Acceptance and rejection of the results of the permanent reconstruction of road infrastructure carried out post-disaster, user satisfaction is the most important in the success of post-disaster recovery projects. In the long run, the mismatch between community expectations and the infrastructure provided by the road will require social costs that burden the public finances. In Manatunge and Abeysinghe's study [12] about the level of beneficiary satisfaction after a decade of the tsunami disaster in Sri Lanka, they show that there are two main challenges in this type of study. First, the level of individual satisfaction is very subjective and depends on personal quality along with the temporal dimension, where it can change with a progressive increase in economic level beneficiaries. The next challenge is that respondents tend not to express their true feelings to avoid a series of questions that ask for an explanation. In overcoming these challenges, they suggest approaches to formulating indirect questions that link beneficiary experiences with expected situations [16].

However, the indicators to determine road infrastructure conditions in the rehabilitation and reconstruction program of post-disaster are largely based on the value of the IRI (International Roughness Index) which the source of data was taken from the IIRMS (Indonesian Integrated Road Management System) output. While the needs of road maintenance should be able to override the traffic performance indicator; those are the degree of saturation (V/C) and the technical requirements to be the minimum width for the national road [13]. On the other hand, the road reconstruction budget cannot handle all the roads in the Palu disaster area. In dealing with subjectivity in the satisfaction of post-delivery road reconstruction, measurements must be taken of the objective attributes of the benefits that can be received, once the evaluation is evaluated by the individual, it becomes subjective and gives rise to a certain level of satisfaction.

In this case, subjective attributes are influenced by so-called 'personal characteristics' which include the socio-demographic and personal characteristics of the individual, as well as the pattern of quality of the use of the road. Normative element in which individuals compare the constructed road with ideal road conditions. It should be noted that this idea has been adapted in assessing satisfaction with the construction of low-cost public roads. For this research, this idea was adapted to present a conceptual framework on long-term user satisfaction in the context of post-disaster road reconstruction. Road reconstruction projects as a hybrid of product and service components, such projects could refer to actions that result in products and the offering of services as well. To discuss the terminology of customer satisfaction, it is obligatory to provide concrete definitions of customer and customer satisfaction as the research would be guided by these definitions.

Case Study: Rehabilitation and Reconstruction-02 Palu Disaster Area

This research used 3 (three) methods combined to get the result of road reconstruction type for each road segment and the priority of the road segment to be reconstructed. The evaluation of the road rehabilitation and reconstruction effectiveness was carried out by comparing the output of the analysis towards the existing road

maintenance program. If the value of the existing program equals the results of the analysis, the conclusion is that the existing road reconstruction program is effective. If the value of the existing program was less or did not meet the needs of the road handling analysis results, the conclusion is less effective. If the value of the existing program exceeds the road reconstruction needs of the analysis results or shows a waste of costs, the conclusion is ineffective.

Three methods are used, namely DM (data mining). The DM method is used to determine the parameters of weight. The budget analysis is also used LCCA and CSI (Customer Satisfaction Index) modification to measure trauma healing satisfaction post-disaster.

This research used primary and secondary data. Primary data were obtained by distributing a set of questionnaires to 100 respondents. Primary data were used for DM to determine the road parameters' satisfaction. The result of data analysis is the ranking of these parameters based on the interest level. The secondary data used were the Performance Index. Data were obtained from Central Sulawesi PJN 1 Satker, BPJN XIV Palu. Also, there was data on road rehabilitation and reconstruction. The secondary data covers all RR-02 projects in Palu Disaster Area. To do modeling with the DM algorithm requires historical data with a fairly long-time span [14]. The data is used as learning data, test data, calibration data, and data validation. Data collected is tabulated and arranged based on the stages of the DM procedure. The collection of data and descriptions as well as data sources used in this study can be seen in table 1.

Table 1. Type of Data andSource

Data Type	Details	Source
Pavement condition	▪ IRI0, ▪ IRI, ▪ Alligator Cracking (m2), ▪ Longitudinal Cracking (mm), ▪ Block Cracking (m2), ▪ Irregular Cracking (m2), ▪ Potholes number (no/km), ▪ Rutting (m2), ▪ Depression (mm) ▪ Deformation (m2), ▪ Structural Patching (m2), ▪ Seal Patching (m2),	DGH
Reconstruction & Rehabilitation History	Resurfacing & Reconstruction schedule	DGH
Cost	Maintenance cost per km Reconstruction cost per km	DGH
Performance	Performance index	DGH & literature study

Post-disaster road reconstruction scenarios are used as input of the cost estimation model with LCCA. The initial step is to make a list of standard rehabilitation and reconstruction strategies that are commonly implemented, then the road rehabilitation and reconstruction model is chosen. If there are road condition data in the year before and after the temporary handling of road conditions, then the data can be used to determine changes in the value of road performance for the next road improvement strategy. The higher the standard value of reconstruction activities and the availability of service data, the estimated cost model will become more accurate. Besides the approach to the standard reconstruction, a major step in the implementation strategy is needed, also known as a jump. Under certain conditions, jump steps are required to immediately reach the desired road performance level or restore pavement conditions that are already too damaged.

The unit price implementation approach, the Ministry of Public Works and Public Housing has records related to the road rehabilitation program in general. Unit prices, which are often stated in units per lane-km, are needed to calculate the cost of road maintenance activities each year. Because rehabilitation and reconstruction are an ongoing activity, it must still pay attention to the level of community satisfaction as trauma healing.

DM algorithm in this study will use the multilayer perception relationship, with one hidden layer using H processing units, prediction relationships, and logistic activation functions 1 / (1 + e (-x)).To find the best H value, do a search in the range {2, 4, ..., 10}, below the internal value (used the amount of training data) around 5-fold

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cross-validation [15]. Based on searches on the network that was built, the value of H that produced the smallest MAD value was selected and DM was retested using all training data. Next to determine trauma healing satisfaction using a customer satisfaction approach. In the business context, in addition to physical products that are produced and consumed by customers, some other demands or demands require companies to have the ability to produce good quality products. In the rehabilitation and reconstruction approach, the community will assess whether the selected steps have succeeded in achieving trauma healing or vice versa. This research model will use a scale of 0-100% to measure the level of trauma healing achievement by the community through questioner distributed to 100 related parties.

Types of Treatment in Post-Disaster Context

Several types of treatment are determined and carried out by the DGH based on road pavement conditions and the type of damage that occurs. Each handling activity is categorized into a class as shown in table 2. However, only a few types of treatment have enough data to analyze. Other types of treatment are not studied or analyzed because the available data is incomplete.

Table 2. Types of Treatment

Code	Treatment	Class	Budget (Billion Rupiah/Km)
T0	Do nothing	-	0
T1	Minor Maintenance	Routine	0,065
T2	Crack Sealing	Preventive	0,12
T3	Patching	Minor/Preventive	0,32
T4	Hot-mix resurfacing	Major	0,71
T5	Hot mill overlay	Major	1,20
T6	Reconstruction	Reconstruction	3,40

The life cycle of the road infrastructure reconstruction consists of procurement; operation and maintenance; as well as renewal or disposal of assets. The procurement phase includes the planning process and comprises a set of feasibility studies to support and justify the needs for the project and its associated costs with regards to economic value LCCA and trauma healing impacts (LCCA–THI). In a post-disaster context, the road reconstruction life-cycle spans between two phases of the disaster management cycle, which are generally coordinated by different institutions

The results of modeling between LCCA and Trauma Healing impact for various IRI scenarios (3.0; 3.5; 4.0; 4.5, and 5.0) using the data mining approach obtained that the level of community satisfaction increases with the number of costs incurred. But at a certain stage, namely when THI exceeds 70%, no matter how much funding and IRI vary, the value of THI is almost the same, so it can be concluded that after passing the 70% THI the financing has reached optimal levels. The description of LCCA financing optimization can be seen in Figure 3.

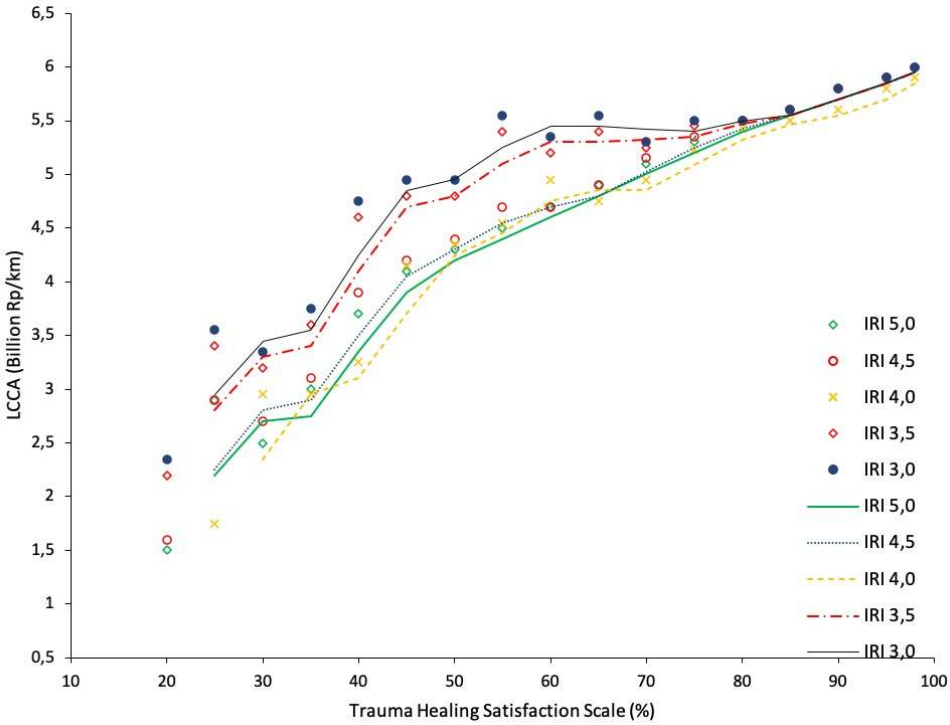

Figure 3. Optimization LCCA-Trauma Healing Satisfaction Scale

The Trauma Healing Impact model is achieved by using two different DM algorithms, the first being used to predict road performance on an IRI scale, while the second is an algorithm for IRI prediction that is linked to the LCCA strategy and financing available at certain ratios. To compile a complete algorithm, a function (f) type of maintenance is first established (as required in table 2 strategy), then the algorithm is arranged based on the type of handling and estimated parameter results in the previous stage. After that, taking the reference value for the type of do nothing (T0), whether determined by the network level or the level of the road segment, is the first step in iteration to derive the parameters from the initial estimated value. Gradually the iteration is carried out following the flow chart for determining the reconstruction strategy. Finally, the optimization capabilities that have been embedded in the algorithm with the addition of the value of the budget benefit and its boundaries are linked to the predicted IRI value, making it easy to calculate the opportunities for each type of treatment.

From the results of the analysis, several principles and best practices in the Disaster Reconstruction Work have been identified to help increase the success of trauma healing, including reconstruction work that must be managed by the community, controlled and owned, socially and culturally acceptable. This should promote mutual support from the community, ask for self-help and ensure voluntary work. The use of environmentally friendly materials that are cheap and environmentally friendly must be used. All available local resources, local talent, subsidies and various government schemes must be utilized. Using simple, latest, cost-effective, research-based technology and original technology that is easily adapted and maintained should be preferred. Finally, labor-intensive technology is a form of community participation.

Conclusion

This paper developed the LCCA-THI model using a data mining approach to produce an optimal rehabilitation and reconstruction scenario. Two objectives in optimization that must be achieved are maximizing the value of roughness and minimizing implementation costs. Both objectives must be achieved simultaneously. The obstacle faced is trauma healing that is soon achieved. Through the data mining approach used to predict IRI, optimization of the reconstruction work will then be performed by separating the types of work. The results showed the grouping of targets of roughness and trauma healing impact scenario, resulting in the most optimal budgeting.

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