Sustainability Analysis of Mining Management on Construction Material in Jeneberang River, South Sulawesi

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Abstract

Mining in Jeneberang River mainly opens to fulfil the demand on construction material in Gowa Regency and Makassar City. River mining can create both positive and negative impacts concerning social, economic, and environmental aspects. Since negative impacts appear due to unmanaged mining that later on will affect its sustainability, it is important to ensure sustainable management of mineral resources exploitation. The main problem may come from non-holistic approach; it becomes a reason that the research needs a holistic approach in assessing sustainability index performance of mining management. The data were collected by using questionnaire consisting of 43 attributes covering social, economic, environmental and institutional dimensions. The selected attributes reflect the notion of mining sustainability and established through literature study, previous researches, and field observation. The objectives of this study are: (1) to analyse sustainability index of mining management in Jeneberang River, and (2) to determine key factors for sustainable management of mining. Sustainability analysis conducted by the method of Multi-Dimensional Scaling (MDS) approach. The result shows that the mining management of construction material in Jeneberang River is sufficiently sustainable with sustainability index achieving 54.2% and have found that eighteen key factors directly influence the sustainability of mining management.

Keywords: mining management, sustainability, Multi-Dimensional Scaling, river mining

1. Introduction

Minerals are vital raw materials in a large number of industries, including construction industry. Extraction and processing of minerals associated with a number of sustainable development challenges are becoming considerably increase, including social, economic, and environmental aspects [1]. It is an important issue for the construction industry as the industry uses a lot of construction material as un-renewable resources and is the main contributor to deplete the resources. In the recent years, mining activities are experiencing strong pressure to comply with good environmental practice. To cope with all challenges of mining industry should be able to increase higher level of sustainability for its performance to be socially and environmentally accepted.

The Brundtland report has defined the sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Sustainability has economic, social, and environmental dimensions which are frequently defined as the three pillars of sustainable development. The integration among the three sustainable fundamentals makes the term of sustainability to be a multidimensional concept [2]. It is obvious that a sustainable development model must integrate comprehensively the social, economic, and environmental components. There are a number of frameworks of sustainability assessment that evaluate performance of industry. Addressing sustainable development requires a holistic approach and river mining industry is no exception.

River mining can be environmentally an effective tool for flood control and channel sustainability, aggrading rivers [3] for sustenance the capacity of rivers, supporting employment and bringing income into many areas [6]. On the other hand, it can create environmental impacts on the rivers. Negative impacts of river mining will influence sustainability status of mining management due to the disturbance to the whole systems.

A question appears consequently that: Is Jeneberang River mining management consistent with sustainable development? In mining, to know whether an activity is sustainable or not, it is necessary to possess a series of indicators that can be a powerful tool to measure social, economic, and environmental performance and to provide information about their contribution to sustainable development [1]. It really needs a holistic approach for controlling mining activities involving social, economic, and environmental aspects which seeks to decrease the environmental impacts associated with river mining while at the same time increasing sustainable economic activity.

Research works and study on the river mining management sustainability for the development is still limited. There has been insufficient effort to measure sustainability with holistic approach. Such a study is required as guidance for further development of the mining without jeopardizing its sustainability aspects. Therefore, the objectives of this research are: (1) to analyse sustainability index of mining management in Jeneberang River, and (2) to determine the key factors for sustainable management of mining. The results of the research are expected significantly to contribute to local government about the necessity of sustainability index assessment regularly.

2. The Jeneberang River

The Jeneberang River is one of the main rivers in South Sulawesi. It is located at Gowa Regency and flows westward across the Province of Sulawesi to the Makassar City. The river is 85.5 km long with a catchment area of 762.01 km2, originating from Mt. Bawakaraeng (2,833 m) which is located around 90 km from Makassar. In the midstream area of the Jeneberang River, there is the multipurpose Bili-bili Dam provides some benefits to the community such as flood control, water supply, irrigation and power plant [4].

On 26 March 2004, gigantic caldera wall collapsed at the east ridge of caldera of Mt. Bawakaraeng. The volume of the collapsed mass was estimated at about 235 million m^3 (originally) and based on more detailed survey the collapse was estimated to be 231 million m^3. Small to middle scale collapse deposits were estimated at 1.6 million m^3 and surface erosion (2004-2009) was estimated at 11.7 million m^3. In 2009, the remains of the collapsed deposit in the caldera were estimated at 82.7 million m^3. Sediment volume flowing into the Jeneberang River was estimated at 162.2 million m^3 [4].

After the collapse of the caldera wall, Jeneberang River was supplied with a large amount of sediment that are mined conveniently and economically to fulfil the needs of Gowa Regency and Makassar City, and become a part of sediment control plan to mitigate the potential debris flow resulted from the Mt. Bawakaraeng collapse.

Throughout the history, the Jeneberang River mining started during the development of the Gowa Kingdom Forts under the reign of Karaeng Tumapa'risi Kallonna in 1525. The Forts were built from stones that are presumed to have been taken from the river [5].

There are currently eighteen mining sites in the midstream of Jeneberang River. The sizes of the mines vary between 2 – 60 hectares. A permit for the extraction of construction material is given by Regent of Gowa Regency. Mining permit requires complete documents of Environmental Impact Analysis (EIA), Environmental Management Program (*Upaya Pengelolaan Lingkungan*, UKL), and Environmental Monitoring Program (*Upaya Pemantauan Lingkungan*, UPL).

3. Research Method

Jeneberang River is used to be a study area assessing its mining sustainability in the process of extracting construction material. The research area covers Parangloe and Bontomarannu Districts (Figure 1). Entry into the mining area needs a permit document obtained from the Department of Mines and Energy, Gowa Regency. The data has been gathered from various related stakeholders through the utilization of questionnaire. A purposive sampling has been carried out of twelve management of mining companies, Head and staff of Department of Mines and Energy, Head and staff of Environmental Agency and Head of Districts and Villages.

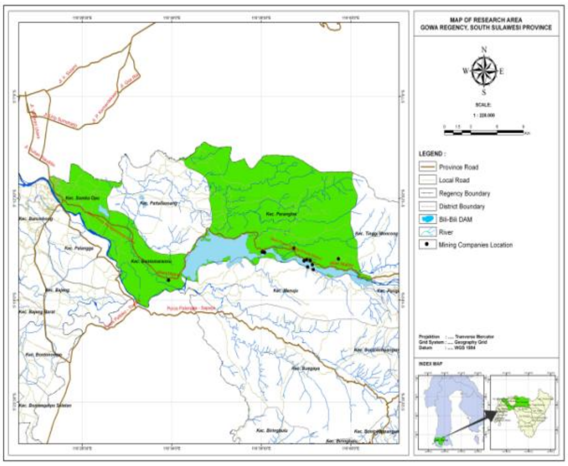

Figure 1. Map of research area

In this research, the sustainability pillars are extended into four pillars for analysis of sustainability. Those are covering social, economic, environmental, and institutional dimensions [6], and consist of 43 attributes. The relative sustainability status were analysed by Rapmines (Rapid appraisal of mining management sustainability), which is a modification of Rapfish (a technique for the rapid appraisal of fisheries status) [8]. The Rapmines is applied using multidimensional scaling (MDS) which is an ordination method, and analysis has been done along with the procedure of Rapfish analysis introduced by Kavanagh and Pitcher (2004).

Multi-Dimensional Scaling (MDS) is a statistical technique to visualize dissimilarity (either or similarity) between pairs of objects. MDS uses Euclidean principles to model data proximities in geometrical space, where distance (d_{ij}) between points i and j is defined as:

$$d_{ij} = \sqrt{\sum\left(x_{ia} - x_{ja}\right)^2} \quad (1)$$

In formula (1) above, x_i and x_j specify coordinates of points i and j for the dimension of a, respectively. These distances are regressed against the original distance matrix. The predicted ordination distance for each pair of samples is calculated. The goodness of fit of the regression is measured based on the sum squared differences between ordination-based distances and predicted by the regression that is commonly known as stress and defined by:

$$Stress = S = \sqrt{\frac{\sum_{ij}(\delta_{ij} - d_{ij})^2}{\sum_{ij} d_{ij}^2}} \quad (2)$$

In formula (2) above, δ_{ij} denotes the value of the proximities between items i and j, and d_{ij} is the spatial distance between them and stress values lay between zero and one. The smaller the stress value, the better the model represents the input data. Another statistic tool is the squared correlation index (R^2), which indicates the proportion of variance of the input data accounted for by the MDS procedure [7].

All attributes in each dimension are scored based on stakeholders' assessment. The scores are in the range of 0 (bad) to 2 (good.) Bad score reflects the most unfavourable conditions for sustainable mining and vice versa. In this research, sustainability status comprises of four categories: (1) 0-25% means unsustainable, (2) 25.01-50% means less sustainable, (3) 50.01-75% means quite sustainable, and (4) 75.01-100% means sustainable.

Attribute leveraging analysis shows the effect of removal of one attribute at a time on the ordination of the river mining sustainability. Leverage (sensitivity) analysis is roughly the average radius of the leveraging scatter for the status of dimension [8].

A convenient way to represent scores on the different axes of sustainability is a polygonal kite. For each of the axes, a score of zero (0%) lies at the centre and a score of 100% lies on the rim of the polygon [9]. Each axis represents one evaluated dimension and can be used to summarize and compare scores from different evaluated dimensions.

4. Sustainability index of mining management

4.1 Social dimension

Social dimension measures the impact of mining industry impact on social issues related to both of mine workers and community. Social dimension consist of 15 attributes, namely: (1) inhabitants participation in the mining management, (2) local employment, (3) age of mine workers, (4) working hours, (5) guidelines of Occupational Health and Safety (OHS), (6) availability of safety equipment, (7) frequency of occupational accidents, (8) availability of occupational accidents insurance, (9) availability of health insurance, (10) availability of Corporate Social Responsibility (CSR), (11) public perception towards mining activities, (12) complaint from inhabitants, (13) frequency of conflict, (14) changes in socio-cultural values, and (15) changes in life quality of inhabitant.

MDS analysis of all attributes shows the value of sustainability index to be 44.95%. It means that social dimension of mining management is less sustainable. Leverage analysis results show that there are six leverage attributes of the social dimensions of sustainability, namely: (1) guidelines of Occupational Health and Safety (OHS), (2) community participation in the mining management, (3) changes in life quality of inhabitants, (4) availability of safety equipment, (5) changes in socio-cultural values, and (6) frequency of conflict.

4.2 Economic dimension

Economic dimension measures how the mining industry determining the economy through the use of mining resource and wealth creation. There are seven attributes namely: (1) volume of material construction demand, (2) companies profit, (3) income of employees, (4) economic conditions of inhabitants due to the mining companies, (5) contribution of mining sector to GDP, (6) mining tax revenue, and (7) the effectiveness of mining tax revenue

MDS analysis is conducted on the seven attributes of sustainability which shows the index value is 45.77%. It means that the sustainability status of economic dimension in mining management is less sustainable. The leverage analysis obtains four leverage attributes, namely: (1) contribution of mining sector to GDP, (2) income of employees, (3) economic conditions of inhabitants due to the mining companies, and (4) volume of material construction demand.

4.3 Environmental dimension

Environmental dimension measures significant operation impacts on environment and consists of ten attributes. Those attributes are: (1) distance from settlement to the mining sites/processing plants, (2) environmental management and monitoring, (3) impact of mining on water quality of the river, (4) nuisance of noise from trucks and crushers, (5) nuisance of dust from trucks and crushers, (6)) impact of trucks on road damage, (7) release of mining waste in the river, (8) impact of mining on civil buildings in the river, (9) impact of mining on riverbanks, and (10) mining companies' concern for the environment.

The MDS analysis of ten attributes shows that the sustainability index value is 66.02%. Based on the category of status, the environmental dimension of mining management is in the category of quite sustainable. Leverage analysis of all attributes obtains four leverage attributes, namely: (1) impact of mining on water quality of the river, (2) impact of trucks on road damage, (3) nuisance of dust from trucks and crushers, and (4) nuisance of noise from trucks and crushers.

4.4 Institutional dimension

Institutional dimension represents the creation and promotion of governmental office concerning legal and regulatory conditions that guarantee the advanced of the mining industry towards sustainability, while on the other hand the mining companies support to the government. There are eleven attributes of institutional dimension, namely: (1) availability of river mining guidelines, (2) availability of regulations and guidelines of OHS, (3) compliance of mining companies with regulations, (4) education on mining environmental and regulations, (5) enforcement of monitoring, supervision, and controlling by institutions (6) availability of labour unions, (7) inter-institutional cooperation, (8) transparency in policy, (9) services of mining permit, (10) mining land use zoning, and (11) number of illegal mining.

MDS analysis result shows that the index value of sustainability is 53.59%, which means that institutional dimension dimensions of mining management is quite sustainable. Leverage analysis conducts on eleven attributes yields four leverage attributes, namely: (1) availability of labour unions, (2) availability of river mining guidelines, (3) mining land use zoning, and (4) availability of regulations and guidelines of OHS.

MDS analysis of 43 attributes indicates that index value of sustainability achieves 54.28%, which means that the mining management currently is quite sustainable.

To evaluate the effects of random error on a process, and to estimate the true value of a statistic of interest, a Monte Carlo Analysis (MCA) was undertaken. A Monte Carlo procedure is useful for studying the effects of scoring error caused by imperfect knowledge or misunderstanding the attributes and scoring guidelines, effects of scoring variation due to differences in opinion or judgement by different people, stability of MDS method for successive runs, incomplete convergence (high stress), data entry errors or missing data, and ambiguous solutions [9]. The result shows that sustainability index between Multi-Dimensional Scaling and Monte Carlo analysis have a little difference of value (α=95%) as shown in Table 1.

Table1. Differences of index value of MDS to MCA

Dimension	MDS	Monte Carlo	Difference
Social	44.95	44.83	0.12
Economic	45.77	46.82	1.05
Environmental	66.02	66.05	0.03
Institutional	53.59	53.68	0.09
Multidimensional	54.28	53.97	0.31

Statistical parameters indicate that all attributes are quite accurate as shown in Table 2 that the value of stress below 0.25 and the coefficient of determination were close to the value of 1.0.

Table 2. Statistical test of sustainability dimension

Dimension	Statistical Parameter		
	Stress	R^2	Iteration
Social	0.13	0.95	2
Economic	0.13	0.93	2
Environmental	0.13	0.95	2
Institutional	0.14	0.95	2
Multidimensional	0.12	0.95	2

To increase sustainability of mining management, it requires improvement in all dimensions, especially at each leverage attribute. Figure 2 represents the sustainability of mining management on construction material in Jeneberang River graphically.

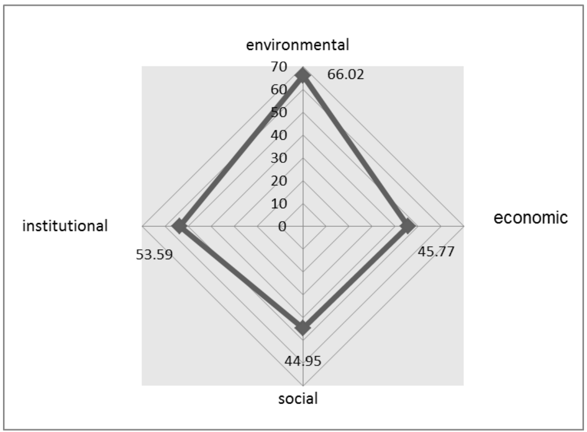

Figure 2. Diagram of four sustainability index of construction material mining management

5. Conclusion

Sustainability status of mining management on construction material from Jeneberang River is categorized as quite sustainable. The research found that two of the four dimensions of mining management have less achievement in sustainable development. To increase the future of sustainable development there are eighteen key attributes as leveraging factors in mining management sustainability.

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