

A PERFORMANCE ASSESSMENT MODEL OF SMALL-SCALE GOLD MINING SYSTEMS IN THE PHILIPPINES USING BENCHMARKING STRATEGIES

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ABSTRACT

The Philippines is one of the top producers of gold in the world. However, small-scale gold mining in the country is still an informal industry in the country. To facilitate competitiveness and sustainability, proper legislation and control of the industry must be present. The study aimed to develop a standard framework and model that would aid the mining companies and the government mining regulatory agencies in assessing their performance in terms of the triple bottom-line objectives, i.e. the environmental, economic, and operational aspects of small-scale gold mining facilities, using a performance-based management framework. This study developed a monitoring and control model in the form of an assessment checklist that covers the aforementioned aspects of a small-scale gold mining facility.

The model was applied and verified by comparing actual ratings and criteria by small-scale mining operators and regional regulatory agencies, and validated by evaluating specific test sites. Applying the assessment model with the test sites show that small-scale gold mining in the sites observed are not at par with all of the standards set by the study which would indicate numerous improvement opportunities as discussed in the study. Usability of the model was also tested to check if the model could be readily used by the respondents. Results indicated that the proposed model can quantify the performance of small-scale gold mining facilities in the country and can potentially be used as a tool for government units concerned with the industry for monitoring such facilities.

Keywords: *small-scale, gold mining, performance assessment, checklist, Philippines*

1. INTRODUCTION

The Philippines is a country full of natural resources, i.e. bodies of water that supports different lives, bodies of land and forests, and veins of minerals and ores. Among the top 20 producers of gold, gold mining has been one of the major sources of income in the communities near gold veins. There are currently around 100,000 miners in the country producing at least 30,000 kg of gold every year (Lücke, 2005). Different types of methods being used in small-scale gold mining include sluicing, panning, cyanidation and amalgamation. All of these processes are observed from current practices and techniques. Likewise, small-scale mining companies in the Philippines also have varying techniques on recovery of gold.

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With very little documentation performed for the industry, there is an apparent lack of a standard for producing gold in the best way as possible in every small-scale gold mining site with consideration to environmental and institutional impacts. Creating and providing a methodology for developing this set of guidelines to agencies, mining operators, and other concerned units would benefit not only them but also the environment and the immediate communities on the sites.

1.1 Rationale of this Study

This research study is geared toward helping the small-scale gold mining industry through the development of a tool or system that would provide the industry with a model of an ideal gold mining extraction. This study investigates the possibility of developing practical solutions and simplified assessment tools to effectively address industry concerns that do not require specialist knowledge, less costly and easy to implement that yield timely results for small-scale gold mining companies or cooperatives that would also aid government agencies in monitoring the mining site's situation. By doing so, the tool would enable small-scale gold mining companies, cooperatives, and respective regulatory bodies to assess their economic and environmental performance. It is the aim that by developing easy-to-use assessment tools, the output would aid the small-scale mining sites in controlling their operations to a standard level of performance. In addition, the expected output would also provide adequate measures to guide regulatory bodies in quick assessments when monitoring the said sites.

This study was also formulated as a part of a research focus of a Philippine government project, "Better Mines" track of the Engineering Research and Development for Technology (DOST-ERDT) that would aid in the life cycle assessment of small-scale gold production systems in the country.

1.2 Research Objectives

This research aim to achieve the following objectives:

- Develop an assessment framework for small-scale gold mining in the Philippines that would address issues on several aspects: Operational, Economic and Financial aspects.
- Develop the checklist for the assessment of the performance of small-scale mining operations in the country touching on the aspects mentioned,
- Develop a system that would allow the users an overview of the system being studied, while giving them the opportunity to identify areas for immediate action.

2. RESEARCH GAP

From all of the researched literature about small-scale mining and performance measurement, it was observed that previous studies were 1) aspect-specific to the industry they are concerned, e.g., environmental, economic, operational, and logistic aspects, 2) policy and regulations generation, and 3) situationer analyses of different areas. For Philippine small-scale gold mining industries, a control model or system has not yet been developed to monitor the over-all performance of artisanal mines in terms of environmental, operational, and economic aspects of the industry. The study would attempt to fill in this gap by providing an assessment checklist that would aid the stakeholders to present: 1) a situationer of the present operations, 2) a performance measurement tool for improvement, and 3) an aid for policy formulation and implementation.

3. CONCEPTUAL FRAMEWORK

The goal of the study is to develop an assessment framework to measure the performance of small-scale gold mining facilities in the country. In essence it is a part of a performance management program that would guide the industry in continuously improving the present system for it to be profitable, environment-friendly, and sustainable. The development of the checklist would follow the performance assessment framework adopted from the Performance-Based Management Special Interest Group of the US Department of Energy. The framework was incorporated in the research to develop a conceptual methodology. The framework is shown in Figure 1.

The conceptual framework integrates benchmarking, performance assessment, and designing for usability from the different stakeholders of gold mining production systems in the country to develop a performance assessment tool for monitoring operations. The target users for this tool are the main stakeholders of the system i.e. the regulatory agencies and the mining operators. The framework would generate an easy-to-implement and ready-to-use heuristic to measure the performance of a gold mining site that ensures that the measures would be fairly accurate to the assessment of the operators and regulators.

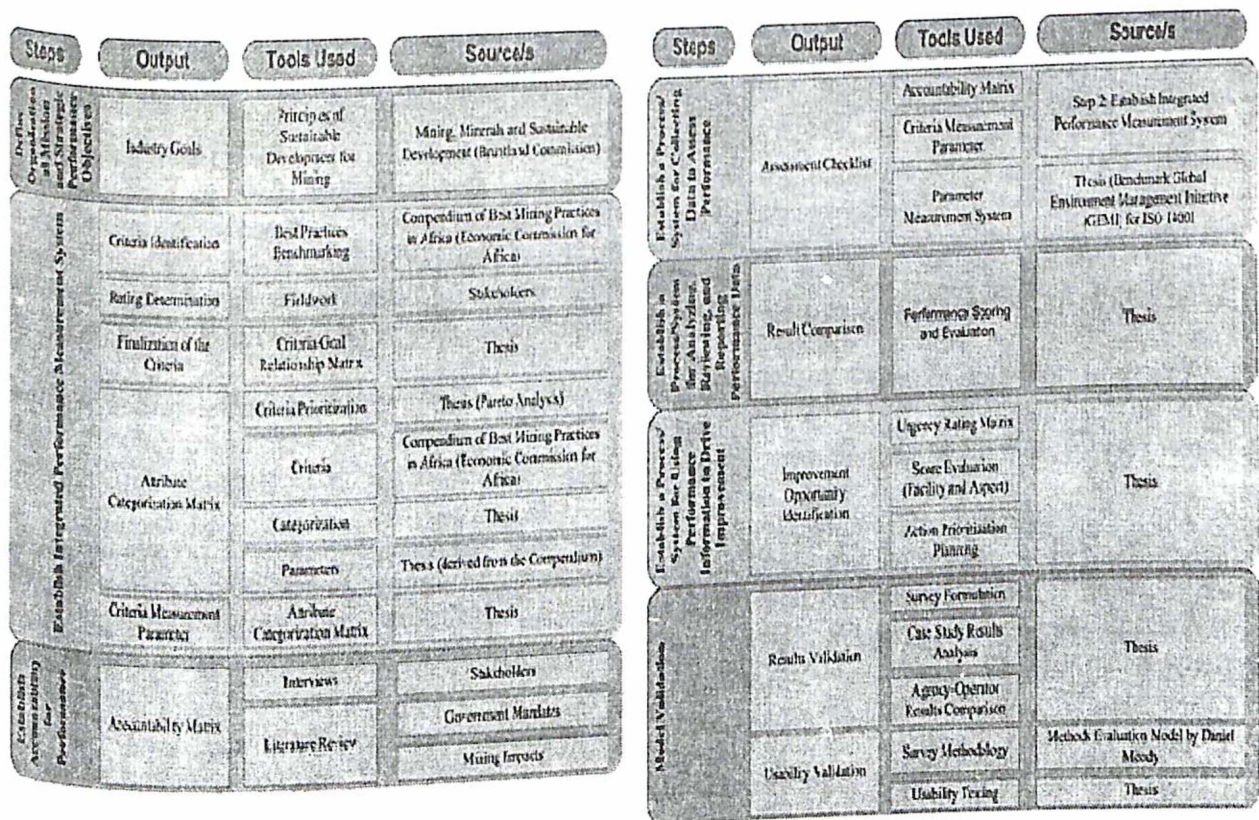


Figure 1. Conceptual Framework

4. MODEL DEVELOPMENT

4.1 *Define Organizational Mission and Strategic Performance Objectives*

The goal of sustainable development is to maximize the well-being of the current generation whilst also providing the ability for future generations to meet their needs. This would ensure that mining would benefit those living today without sacrificing the future generations in aspects to be identified (Bruntland Commission, 2002). The Mining, Minerals and Sustainable Development (MMSD, 2002) project provides a framework for sustainable development based on a set of agreed principles, which were grouped into four areas namely the Economic Sphere, Social Sphere, Environment Sphere and Governance Sphere. Each sphere identified several principles falling under them.

As these principles are in accordance to the goal of sustainability of the small-scale gold mining industry of the stakeholders, specifically the Mining and Geosciences Bureau of the Department of Environment and Natural Resources, these are the goals to keep in mind when developing the model for the assessment checklist

4.2 *Establish Integrated Performance Measurement System*

Performance measurement systems succeed when the organization's strategy and performance measures are in alignment and when every stakeholder conveys their own mission, vision, values, and strategic direction to the industry.

The performance measurement system that would be formulated is the simplified assessment checklist for measuring the economic, environmental, and operational performance of a certain small-scale gold mining facility or site. The checklist would involve the goals as stated in the previous section with the performance measures to be obtained through benchmarking the best practices. A listing of the criteria to be tackled by the study is grouped according to relevance as obtained from the Compendium of best mining practices in Africa (Economic Commission for Africa, 2002).

To trim down the number of criteria to actually obtain the key performance indicators that would reflect the goals of the industry, a Criteria-Goal Relationship Matrix was formulated. Criteria were identified from the Compendium and the Goals were identified from the Sustainable Development framework for sustainable mining.

The goal of the procedure is to define the prioritization of the criteria with respect to the goals identified earlier. A matrix of both items is made to compare each per factor. The scores obtained from the Matrix are determined to limit the number of criteria to prevent dilution of information. For this, only the top 80% priority of the criteria was to be included in the final model. The final list of criteria is shown below.

Table 1.
Final Criteria with Adjusted Weights

		Criteria	
Economic	Minerals marketing	Regulation of minerals marketing	3.75%
		Licensing of private mineral dealers	2.90%
		Strategies/incentives to discourage illegal trading	3.58%
		Incentives to encourage value adding practices	3.07%
Operational	Process	Process flow schemes	3.92%
		Waste management schemes	3.92%
	Technology	Availability of channels for access to technology	3.41%
		Programs for promotion of cleaner and more efficient technology	4.60%
		Technical training and awareness programs	5.79%
		Promotion of value-adding techniques	3.24%
	Technical assistance programs	Specific technical assistance programs	3.92%
		Specialized training institutions	4.09%
		Miners' access to information	7.67%
	Environmental	Environmental management, health and safety	Specific environmental legislation and regulations
Procedures for environmental impact assessment			4.43%
Procedures and financing for site rehabilitation			4.26%
Legislation on health and safety			4.26%
Monitoring, reporting and data collection			4.77%
Institutional capacity		Institutional network	7.84%
		Adequate human and financial resources	3.58%
		Specialized small-scale mining units	3.24%
		Small-scale miners' organizations	8.18%

4.3 Establish Accountability for performance

To assure the success of the performance measurement system, all results and improvements must be handled by set individuals or groups. This would ensure that every aspect and every issue that was discovered in the process of performance measurement would be properly addressed. The accountability of each stakeholder is different depending on the criteria and the issue involved. Table 2 represents the Accountability Matrix for the small-scale gold mining industry, in general. The table shows which stakeholder is affected by the respective criteria while holding the accountable group responsible based upon legal mandates and present relations with each stakeholder. These assignments were obtained from interviews of the officials and stakeholders involved.

Table 2.
Accountability Matrix

Criteria		Stakeholders						
		Mining Operators	Mining Organizations	Local Government Unit	Mines and Geosciences Bureau	Environmental Management Bureau		
Economic	Minerals marketing	Regulation of minerals marketing	R	a	a	a		
		Licensing of private mineral dealers	a	R	a	a		
		Strategies/incentives to discourage illegal trading	a	a	R	a		
		Incentives to encourage value adding practices	a	a	R	a		
Operational	Process	Process flow schemes	R	a	a			
		Waste management schemes	R	a	a	a		
	Technology	Availability of channels for access to technology	a	a	R	a	a	
		Programmes for promotion of cleaner and more efficient technology	a	a	R	a		
		Technical training and awareness programmes	a	a	R			
		Promotion of value-adding techniques	a	a	R			
	Technical assistance programs	Specific technical assistance programmes	a	a	a	R		
		Specialized training institutions	a	a		R		
		Miners' access to information	a	a		R		
	Environmental	Environmental management, health and safety	Specific environmental legislation and regulations	R		R	a	a
Procedures for environmental impact assessment			R		a	R	a	
Procedures and financing for site rehabilitation			R	a		R	a	a
Legislation on health and safety			R	a	a	R		a
Monitoring, reporting and data collection			R	a	a	a	a	a
Institutional capacity		Institutional network	a	R	a		a	
		Adequate human and financial resources	R	a	R		a	
		Specialized small-scale mining units	a	R		a		
		Small-scale miners' organizations	a	R		a		

a - Affected Stakeholder
R - Accountable Stakeholder

4.4 Establish a Process/System for Collecting Data to Assess Performance

To assess the performance of the facility, the model used an assessment checklist. From the previous sections regarding the formulation of the criteria, the checklist would be a three-dimensional matrix with the dimensions, 1) the aspects of the gold mining site to be tested, 2) the criteria for best practice, and 3) the parameters of the criteria.

The assessment checklist for small-scale gold mining is a series of questions that would incorporate a scoring system in which the stakeholder would answer to evaluate the current system in their mining location. The checklist evaluation was benchmarked from an assessment checklist from the Global Environment Management Initiative (GEMI) for ISO 14001 (GEMI, 2000). The checklist provides the criteria to be monitored and with that the minimum level of improvements to be made by the company to be at par with the standards made for small-scale gold mining industry in the Philippines.

4.5 Establish a Process/system for Analyzing, Reviewing, and Reporting Performance Data

Analysis is one of the most important steps in performance-based management. To achieve the performance assessment of small-scale gold mining operations, the checklist would be analyzed through evaluation of the scores to obtain an over-all score for the location being tested. The computation of the scores could be seen in Table 3 and Table 4.

Table 3.
Generated Values for Each Criteria

Criteria	Parameter	Criteria Weight	Score
"criteria"	"parameter"	W	S

Table 4. Criteria Computation for each Column

Sum of Scores	Weighted Score	Evaluation	Total Score
= sum of the three parameters for each criteria Equation 1 Sum of Scores $SS_c = \sum_{i=1}^3 S_i$	= product of sum of score and criteria weight Equation 2 Weighted Score $WS_c = SS_c * W$	Equation 3 Passing Criteria Score $SS_c \geq 3$ Equation 4 Failing Criteria Score $SS_c < 3$	= sum of all the SSC over all criteria Equation 5 Total Score $TS = \sum_{c=1}^c SS_c$

4.6 Establish a Process/System for Using Performance Information to Drive Improvement

This step aims to establish the system to utilize the information to be obtained from the checklist.

There are many ways by which information to be obtained may be used. These include:

- Driving performance improvement
- Benchmarking (including the use of performance data to accomplish benchmarking, and the use of benchmarking data to drive improvement)
- Changing management processes through reengineering, continuous improvement, and process improvement.

For the evaluation of the criteria, it was observed that at least 50% of the sum of scores should be given to confidently state that the site passes said criteria. This implies that:

- 1) at least one parameter should have the best situation (score=2) and one average situation (score=1); or
- 2) the three parameters are present with average situation (score=1).

The aforementioned conditions are the goals that would indicate a passing condition for the said criteria.

After answering the checklist, the evaluator should add up the scores for the questions and compare the sum of scores to a rating system in order to evaluate the state of the site in terms of the urgency or gravity of the criteria. Table 5 shows the equivalent implications of the rating system that this study developed.

Table 5.
Urgency Rating Matrix

Score	Interpretation
0 – 50%	Urgently needs attention. Refer to the checklist to determine the main concern to attend to (i.e. 0 score)
51 – 67%	Needs attention as the facility meets many, but not all, of the requirements established under the criteria.
68 – 100%	The aspect in study meets all the necessary requirements and performs above expectations. Check other aspects. (Please indicate the other aspects that must be checked.)

4.7 Model Validation

To validate the model proposed by this study, the formulated checklist was applied to some of the stakeholders directly related to the production of the gold. The study involved case studies from major gold mining sites in the Philippines, namely in Benguet, and Camarines Norte. The validation of the model was performed by directly observing their operations and interviewing the operators about their practices. However, the validation of the model was only conducted in Benguet and Camarines Norte. The case study participants are shown in Table 6.

Table 6.
Case Study Participants

Location	Stakeholder	Organization	Name/Position	Position
Benguet	Mining Operator	Southern Ucab	Alfred Bugnosen	President
		Camp 6, Benguet	Guillermo Padoyan	President
		RHINO	James Martin	President
	Regulatory Agency	MGB-CAR	Fernando Guevara	OIC–Small-Scale Division
Camarines Norte	Mining Operator	JG Mining	Darwyn Morada	Technical Manager
	Regulatory Agency	Local Government Unit	Olfí Zabala	Environmental Specialist

For the validation, each participant was asked to undergo the model validation process, which was accomplished in about 1 hour and was done as follows;

1. Research Briefing
2. Model Introduction
3. Model Application
4. Model Validation survey

The need for testing the usability of the model was identified to ensure a higher probability that the end-users would adapt the system. The validation of the checklist was performed to properly measure how the target end users would use and perceive the output of the research. The identified criteria to be used in the evaluation survey pertain to the Methods Evaluation Model by Moody (Moody, 2003). A Likert scale was used to obtain the answers of the participants to each question.

4.7.1 Performance Assessment Validation Results

The model was applied to the 6 stakeholders who participated in the validation of the performance assessment checklist. The validation involved the following steps:

1. Obtain Site Performance Assessment from Mining Companies
2. Obtain Site Performance Assessment from Regulatory Agency
3. Comparison of the Assessments of Stakeholders

The implementation of the validation procedure was done using Minitab and the results are as follows:

Table 7.
Paired t-test results between Agency and Operator

Regulatory Agency	Mining Operator	Difference (Average)	Paired t-test (p-value)
MGB-CAR	Camp 6	0.0408	0.177
LGU-Region5	JG Mining	0.0018	0.944

Based on the results, the following are the findings:

1. There is no significant difference in the results obtained for each category presented in the checklist for both areas. The self-assessment by the operator and the assessment of the agency on the operator are significantly the same, i.e. both of them have measured the same performance criteria and measured similarly.
2. The model can be used as a self-assessment and an outside assessment of the same facility and come up with the same results.

4.7.2 Usability Assessment Validation Results

The checklist was also tested for its usability in the three areas specified:

1. **Ease of Use** – to determine if the checklist can easily be adapted by the end-users
2. **Usefulness** – to determine if the end-users can verify if they perceived it as usable
3. **Intent to Use** – to determine if the end-users have the intent to use the model

A survey was conducted to test this aspect. Results are shown in Table 8.

Table 8.
Usability Validation Results

Variable	Mean	95% CI	T	P	Remarks
E1	4.143	(3.793,4.492)	8	0	Positive
E2	4	(3.466,4.534)	4.58	0.004	Positive
E3	4.143	(3.505,4.781)	4.38	0.005	Positive
E4	4	(3.245,4.755)	3.24	0.018	Positive
E5	3.286	(2.257,4.315)	0.68	0.522	Indifferent
E6	2.857	(1.733,3.981)	-0.31	0.766	Indifferent
U2	4	(3.466,4.534)	4.58	0.004	Positive
U3	4.286	(3.834,4.737)	6.97	0	Positive
U5	4	(3.466,4.534)	4.58	0.004	Positive
U6	4.143	(3.793,4.492)	8	0	Positive
U7	4.143	(3.793,4.492)	8	0	Positive
U8	4.143	(3.505,4.781)	4.38	0.005	Positive
U9	4.286	(3.834,4.737)	6.97	0	Positive
U10	4	(3.466,4.534)	4.58	0.004	Positive
I1	4.143	(3.793,4.492)	8	0	Positive
I2	4	(3.466,4.534)	4.58	0.004	Positive
I3	4	(4.000,4.000)	*	*	Positive

The results indicate that all of the analyzed questions were positive. This means all of the respondents think that 1) the model is easy to use, 2) the model is useful, and 3) they may use the model in the future.

5. CONCLUSIONS

Legalization, intervention and control are keys to eliminating unacceptable work practices and are a necessary prerequisite for removing operational constraints limiting productivity and competitiveness (Zairi, 1996). To increase the level of productivity and competitiveness of the country's artisanal gold mining industry, proper implementation of legalization, intervention and control are essential. Studies have shown that there is still room for improvement in the industry especially in the aspects discussed in the research. The study used the Performance Management Framework to:

1. Identify benchmarks and standards targeting the Economic, Environmental, and Operational Aspects of the small-scale gold mining industry in the country;

2. Generate a Rating System that correlates the Goals of the industry and the Criteria identified;
3. Develop the Assessment Checklist as the evaluation tool for the small-scale mining facilities;
4. Develop a system for Analyzing, Reviewing, and Reporting information gathered to drive Improvement in the industry.

Results indicate that the proposed model can effectively quantify the performance of small-scale gold mining facilities in the country as shown in the comparison between the regulatory agencies' and the mining operators' evaluation of the operator's facility. Usability testing was also accomplished in the research to properly ensure that the model formulated was appropriate for the target end-users i.e. the mining operators and the regulatory agencies. The model was tested on its Ease of Use, Usefulness, and the Intent of Use of the participants in the case study. The survey received positive feedback as was shown in the test for usability. This indicates that the Usability of the Assessment Checklist was established.

Through the framework, the development of a performance assessment tool using performance management and benchmarking methodologies was achieved. It was validated using through the use of statistical tests to determine the legitimacy of the outputs it produces and also to determine the usability of the tool itself.

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