A new hybrid decision support tool for evaluating the sustainability of mining projects

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ABSTRACT

The integration of sustainable development challenges and opportunities into the decision making process during the design and/or implementation of multi-disciplinary mining projects is generally not supported by decision support systems (DSS). A new hybrid decision support tool, which features an integrated assessment of sustainable development issues as they apply to mining projects, is hereby proposed. The proposed DSS framework, named "Acropolis DSS", can be used to assist involved stakeholders in critical decisions, especially when addressing issues such as stakeholder participation, transparency, and trade-offs. The proposed DSS is based on a multi-criteria decision analysis combined with the multi-attribute utility theory.

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1. Introduction

Sustainable development (SD) is the development that "...meets the needs of the present without compromising the ability of future generations to meet their own needs (...). Such equity would be aided by political systems that secure effective citizen participated in decision making and by greater democracy in international decision making...", as stated in the *Report of the World Commission on Environment and Development*, United Nations, in 1999 [1]. Furthermore, a "sustainable path" (SP) towards SD is described as "one that allows every future generation the option of being as well off as its predecessors", as stated in the *Commission on Geosciences, Environment, and Resources*, of the US National Research Council (NRC), in 1994 [2]. In accordance to the European Commission priorities, sustainable development is a fundamental objective of the European Union (EU) under the Lisbon Treaty, stated in *Mainstreaming Sustainable Development into EU Policies: Review of the European Union Strategy for Sustainable Development*, Commission of European Communities, in 2009 [3].

The 2030 Agenda for sustainable development of the United Nations set out 17 sustainable development goals (SDGs) with 169 associated targets [4]. This Agenda is a plan of action for people, prosperity and the planet. All countries and all stakeholders, acting in collaborative partnership, should consider implementing this Agenda. These SDGs and targets will stimulate action over the next 15 years in areas of critical importance for humanity. Quality, accessible, timely and reliable disaggregated data will be needed to help with the measurement of the progress. In accordance to the UN 2030 Agenda, such data is considered a key to decision making for SD. As stated in *Transforming our World, the 2030 Agenda for Sustainable Development,* United Nations, in 2015, the Agenda called upon all private business, from micro-enterprises to cooperatives and multinationals, to apply their creativity and innovation to solving sustainable development challenges.

In addition to these challenges, the extractive industry may be confronted by the unwanted effects of environmental policy mechanisms, energy efficiency issues related to specific operational processes, such as loading and hauling or the environmental effects caused directly by the excavation process, and low carbon issues associated with production, supply chain and operations management perspectives [5–8]. As a result, decision making is becoming a complex process that should utilize logic and inclusive reasoning to make informed decisions based on available information. Decision making is not a straightforward procedure; the right decisions and selection of optimal alternatives are not easy and demand time [9]. When applied to SD, this vital process involves evaluation of a number of outcomes within a social, economic and environmental framework, although many times balancing social, economic, and environmental costs and benefits can be a subjective process. In any case, such assessments should

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eventually promote responsible and sustainable development—a core aim of many international policies [10].

Furthermore, the "Social License to Operate" has become an important prerequisite for the extractive industries, since it helps minimize the business risks related to probable social unrest or opposition stemming from the realization of mining projects. Research has shown that in order to achieve a more socially sustainable mining industry, where social conflict around mining operations is minimized and the public is able to experience the benefits of resource development, both the mining industry and governments need to review their methods of engaging with citizens to build trust in those stakeholder relationships [11]. Society is today sensitive in the case of environmental protection, transparency and means of communication and has adopted a general pro-environmental behavior; this may cover a wide range of initiatives spanning from large mining projects to personal consuming habits. Furthermore, consumers require information that will help them judge the value of environmentally conscious products by themselves and put more emphasis on the transparency of label certification results than the involvement of experts [12].

The tools that can potentially contribute to the assessment of SD and support decision making have been divided into three main categories: (1) indicators and indices, (2) product related assessment, and (3) integrated assessment [13]. Typically, such indicators can be non-integrated (e.g., environmental pressure indicators), regional flow indicators (e.g., based on an input/output analysis) or integrated (e.g., representative of a well-being index). The second category includes product related tools that focus on flows in connection with production and consumption of goods and services. Finally, the third category of tools is used for supporting decisions related to a policy or a project in a specific region. A decision support system (DSS) is defined as a software based tool assisting in the decision-making process by interacting with both internal and external users and databases, while utilizing standardized or specific algorithms for problem solving [14,15]. Multi-criteria decision-making (MCDM) "deals with a general class of problems that involves multiple attributes, objectives and goals" [15,16]. This paper proposes a new hybrid DSS tool which is based on an integrated indicators-based SD assessment process for supporting decision making in mining projects. The developed DSS tool combines baseline indicators, i.e., evaluated before starting up a project, and indicators evaluated during project implementation and after project completion. The tool considers local, regional, country, and international conditions during these three distinct time frames. For example, project stakeholders can compare the economic activity in an area before starting up a project to the economic levels achieved during project implementation as well as after the project has been completed. Thus, any advantages and disadvantages with respect to SD principles can be easily outlined. In addition, this work integrates the proposed DSS with the sustainable development framework presented and discussed in previous works [17,18].

This paper is organized as follows: the background section reviews and discusses different DSSs that have been proposed in a sustainable development context as applied to the energy sector, the extractive industries and some industrial systems that have an environmental component; sustainable manufacturing, which is an emerging discipline, is not discussed here. Subsequently, the developed DSS model, which incorporates different SD indicators as applied to mining projects with respect to sustainable development challenges and opportunities, is presented. The proposed system, named "Acropolis DSS", can be used to assist involved stakeholders in critical decisions, especially when issues such as stakeholder participation, transparency and trade-offs are addressed. The proposed DSS is based on a multi-criteria decision analysis (MCDA) combined with the multi-attribute utility theory (MAUT). Multi-criteria decision analysis methods have been developed to support decision makers in their unique and personal decision process; MCDA is a discipline of operations research that encompasses mathematics, management, informatics, psychology, social science and economics [19]. The multi-attribute utility theory is based on the main hypothesis that every decision maker tries to optimize, consciously or implicitly, a function which aggregates all their points of view [19]. In MAUT, the decision maker's preferences can be represented by a function, called the utility function [20]. This function is not necessarily known at the beginning of the decision process, so the decision maker needs to construct it first. Finally, the conclusions of this study are presented and future research initiatives are discussed.

2. Background

The concept of applying a DSS with respect to SD principles in technical projects is not new. In this section, several such systems are evaluated as published in the international literature. However, none of these systems has been directly applied to mining projects.

Two such models, which address stakeholder input, have been recently proposed. The first one developed a DSS based on MCDA to promote community involvement in the case of mining projects [21]. The MCDA which was used to assess the most relevant factors for stakeholder strategy evaluation, includes perspectives upon which new alternatives might be developed, and assesses these alternatives based on multiple economic and social criteria. The preference function assigned to each criterion illustrates how each stakeholder changes his/her preference with the difference in performance level for two alternatives. A multi-criteria preference index was created by the weighted average of the corresponding preference functions for each criterion utilizing the weighting factors assigned previously by each stakeholder to every criterion. Although the model is based on the three SD pillars (social, economic, environmental) it is only focused on the preliminary stage of mining projects and does not cover the mining stage and the stage following the completion of a mining project. The model follows the "people-first" approach to support the involvement of local communities before a mining project is initiated and especially at the design stage. Also, the model does not intend to incorporate the criteria and indicators utilized into the broader SD policy context i.e., the achievement of the United Nations SDGs as they were stated at the UN 2030 Agenda for sustainable development [4].

The second model was proposed by Poplawska et al. who created a DSS utilizing fuzzy logic in order to assess and categorize stakeholders involved in an SD process in a set of groups [22]. In order to categorize the stakeholders in groups, their importance was evaluated by indicating the exact degree of membership to a particular interest group. The fuzzy set theory allows intermediate degrees of membership between elements in a given set. Membership is defined based on criteria which are selected from a list of attributes and is assessed by the decision maker. Thus, by calculating fuzzy scores for every stakeholder, the model provides the ranking of stakeholders. The authors utilized this DSS in order to construct the profile of key extractive sector stakeholders and measure their salience in a corporate social responsibility context.

Similar systems that have been fully or partially applied to the extractive industries include a DSS model developed by Hunt et al. which was based on MCDA and combines two other tools: a decision rationale and a probabilistic forecasting tool [23]. The DSS was applied to the energy sector in order to determine the recommended sources of electricity generation in different locations in the United Kingdom, paying attention to water consumption and water purification using hybrid power and desalination plants.