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# Agent-based modeling framework for modeling the effect of information diffusion on community acceptance of mining

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ABSTRACT

Mine managers find it challenging to predict changes in the level of acceptance of their mining projects due to changes in associated social, environmental and technological factors. To address this challenge, this study presents a: (i) framework for modeling the effect of information diffusion on community acceptance of mining using agent-based modeling (ABM); and (ii) case study to illustrate the framework. The model, built in Matlab, defines individuals in the community as independent agents that interact with other agents for information. The agents' utility function is derived from discrete choice models. Drawing on data from the literature, a case study was used to illustrate the framework. The results indicate that changes in agents' perception of air pollution have a significant effect on acceptance of mining while demographic factors do not. The proposed framework could be applied in other sectors besides mining and provides stakeholders a tool to integrate sustainability into design and management choices.

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## 1. Introduction

Mining provides raw materials, which are important to all services and infrastructure used by society (Martens and Rattmann, 2001; ICMM, 2012b). In spite of these benefits, the negative impacts of mining have not gone unnoticed. Various stakeholders have been expressing concern about the negative social and environmental impacts of mining as concerns about sustainable development increase in soceity (Epstein and Roy, 2003; Prno and Slocombe, 2012; Dechant et al., 1994). Stakeholders now expect that mining takes place in an economically, ecologically and socially acceptable manner (Martens and Rattmann, 2001). It is becoming clear that communities, civil society, investors or governments will not allow unsustainable mining and metal companies so proactive response is imperative (World Economic Forum, 2014). If mines are unable to meet expectations, they will find it difficult to acquire and maintain their social license to operate (SLO) (Thomson and Boutilier, 2011).

Mineral developers need to gain and maintain a SLO to avoid potentially costly political and social unrest and consequent exposure to business risk (Prno, 2013; Moffat and Zhang, 2014). SLO exists when a mining project is seen to have broad, ongoing approval and acceptance of society to conduct its activities (Joyce and Thomson, 2000; Thomson and Boutilier, 2011). The success of a mining project from permitting through to mine closure is dependent on its social license to operate in the local community (Thomson and Boutilier, 2011).

Previous work to understand community acceptance of mining projects have generally been qualitative (Ivanova and Rolfe, 2011; Que and Awuah-Offei, 2014; ICMM, 2012a; Boateng and Awuah-Offei, 2014; Thomson and Boutilier, 2011; Prno, 2013; Moffat and Zhang, 2014; Nakagawa et al., 2012; IFC, 2014; Que, 2015). The few quantitative approaches do not predict changes over time. However, SLO changes over time (Yates and Horvath, 2013), and therefore, mine managers need approaches that allow them to predict changes over time due to interactions between the technological (the mining), social and ecological systems (Que and Awuah-Offei, 2014; Que et al., 2015).

Changes in the community's perception of mine characteristics and impacts, which affect SLO, can be described as diffusion of information (perceptions) over a social network. This is particularly true if the changes in perceptions (or opinions) are mainly due to interactions with others. In such situations, new perceptions or opinions can diffuse over a network of people in the mining communities. Eventually, these new perceptions can lead to changing acceptance levels of the mining project. Continual surveying and engagement can help monitor such changes. However, such practices are expensive and time-consuming. Hence, mine managers need tools (including computational models) to predict such changes without (or in addition to) repeated surveys. Such tools do not currently exist and researchers have not given the problem the needed attention.

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This work is intended to fill this gap by proposing a framework for understanding how levels of community acceptance change over time given changes in social and environmental attributes of a mine. The specific objectives of this work are to: (i) propose a framework for modeling the effect of information diffusion on community acceptance[3] of mining using ABM; and (ii) illustrate the framework using a case study. The case study, which uses data from Que (2015), examines the effect of agents' changing perceptions of the levels of air pollution on the level of acceptance of a mine. This work accounts for the effect of new information about the mine's relevant sustainability impacts on changing perceptions. The purpose is to understand how in a given mining community, interactions and communications among the people in the presence of changing perceptions of mine impacts can influence community acceptance of the mining project.

Modeling the effect of information diffusion on community acceptance of mining requires a complex adaptive system framework such as agent-based modeling (ABM) (Miller and Page, 2009). ABM is particularly suitable in this case because it is much easier to characterize the interactions between individuals, how such interactions might influence an individual's perceptions and preferences, and the uncertainties surrounding such processes for individuals than for the entire population. ABM offers the opportunity to explicitly model the social interactions between individuals of differing characteristics and takes into account the structure of social network (Kiesling et al., 2011). ABM models can capture dynamic and emergent behavior in ways that cannot be achieved by other approaches (Macal and North, 2010; Bonabeau, 2002).

Other researchers have used ABM to describe the effect of information diffusion and innovation on adoption of several green technology products (Palmer et al., 2015; Shafiei et al., 2012; Schwarz and Ernst, 2009). This prior work provides a point of departure for the present work.

This work contributes to improving mining sustainability practice and research and can inform broader discussions about the interactions between large engineering and manufacturing projects and their host communities. It will help facilitate better inclusion of community views in evaluating design alternatives during project design and planning (Howard, 2015; Soste et al., 2015). This helps project managers acquire informed consent and social license to operate, which are sustainable outcomes (Szablowski, 2010; Yates and Horvath, 2013). Also, this work contributes to recent research at the boundaries of social science, complex adaptive systems and sustainability (Fiksel, 2003; Schluter et al., 2012). Mines, which are often relatively large enterprises in small rural communities, are unique examples of the interaction between technological systems created for and by industry and the social and ecological systems that host them. Although, there have been some attempts at incorporating discrete choice theory and ABM (Araghi et al., 2014; Hunt et al., 2007), the authors could not find any work that used them in conjunction with diffusion through social networks to understand the dynamic relationship between perceived project sustainability attributes and community views.

This paper is structured as follows: Section 2 describes the proposed modeling framework; Section 3 discusses model validation; Section 4 presents the case study; Section 5 provides a general discussion; and Section 6 presents the conclusions.

## 2. Modeling framework

The major determinants of the level of community acceptance of a mining project can be classified into characteristics and impacts of the mine, and demographic factors (Que et al., 2015). Mines have social, environmental and economic impacts. For instance, Que and co-workers found that the relevant characteristics of a mining project include the life of the project (the project duration), buffer between the mine and residents (how far is the community or communities are from the mine), decision making mechanism for permit approval, and availability of independent and transparent information on potential impacts of the mine. These impacts and characteristics depend on the type of mine and technology (equipment, engineering design, and mitigation techniques) employed in mining.

To model the level of community acceptance of mining, the model has to account for these determinants. ABM is the most appropriate approach because of its ability to account for agent heterogeneity and social structure. Thus, it allows the modeler to explicitly model the social interactions between individuals of differing characteristics and to take into account the structure of social network (Kiesling et al., 2011). In ABM, the model state "emerges" from the state of individual agents in the model. The level of community acceptance could be modeled from deducing the percentage of individual agents that prefer a proposed mining project over the status quo. To accomplish this, the determinants of individual preferences for mining projects have to be incorporated into the agent's utility function, which determines the agent's state (prefer or not). In our proposed framework, these determinants are incorporated into the model as agent attributes, which can change with time. The general framework is presented in Fig. 1.

This framework (Fig. 1), implemented in MATLAB 7.7 2014, predominantly relies on two input data sets: (1) demographic data (e.g. age, gender, education, number of children, length of residence, location, etc.); and (2) non-demographic data (e.g. job opportunities, income increase, noise pollution, traffic increase, crime rate, mine life, mine buffer etc.), which define the mine impacts and characteristics. These two data sets, which are modeled as agents attributes, are used to describe agents' motivations (utility function). The examples of these data sets in this paper are not exhaustive. The factors that influence an individual's preference for a mine differ from one situation to the other. Thus, the number and type of factors in the model depend on the number and type of factors that the analyst deems important for describing an individual's preference. For example, Que (2015) found the individual's level of education to be statistically significant but not the number of children. Ivanova and Rolfe (2011), on the other hand, found the number of children to be significant but did not consider level of education (Table 1). Also, whereas Que (2015) found 20 (4 demographic and 16 non-demographic) factors to be relevant, Ivanova and Rolfe (2011) found 13 (8 demographic and 5 non-demographic) factors to be relevant.

The algorithm initializes agents at the beginning of each iteration. In this step, agents are created with various attributes depending on the input. The important state variables for this framework are the "decision" and "preference" variables. The decision variable is used to describe whether the agent is participating in the decision (above 18 years old and alive) or not (below 18 years or dead). Agent preference state describes whether the agent prefers the proposed mining project over the status quo or not, and is determined using the decision criteria based on the utility function. Some agent attributes are dynamic as they change over time. These attributes are updated at each time step. These include age and agent's decision state (i.e. alive or dead, or attained 18 years). In order to use the model to understand the effect of information diffusion on community acceptance, at least one non-demographic attribute has to be dynamic. Also, such attribute should be affected by information diffusion over a social network. The model is run for a number of iterations to adequately estimate the output from Monte Carlo simulation, which is used to model stochasticity in the model.

The three major aspects of this framework are the approach to modeling agents, topology, and changing perceptions. These are discussed in detail in the following sub-sections with a discussion of minor miscellaneous constructs.

[3] As used in this paper, "community acceptance" means the individuals (agents) prefer the project over the status quo. This may be more than "acceptance" but less than "approval," in SLO parlance (Thomson and Boutilier, 2011).

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