System Dynamics for a Sustainable Mining Industry

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ABSTRACT

The demand for minerals, metals and rare-earth elements is growing globally to support the transition towards low-carbon energies (World Bank, 2017). While the Resources Sector traditionally relied on strong engineering expertise to maximize extractive performance and ore value, the industry at large is facing fast changes in socio-economic dynamics and growing complexities in project developments (Maennling and Toledano, 2019). Recent research undertaken under the Complex Ore Bodies (COB) program within the Sustainable Minerals Institute (SMI) at the University of Queensland (UQ) suggests that a rise in commodity price will be insufficient to ensure a sustainable supply of metals into the future, because prospective developments are facing a high proportion of environmental, social and governance (ESG) risks that are not directly price-sensitive (Valenta et al., 2018). The resource sector has a unique opportunity to turn these challenges into sustainable business practices that will deliver value to society, and contribute to a long-term positive legacy beyond the closure of the mine, by rethinking traditional mine planning methods.

Mining companies increasingly recognize that their operations are embedded within broader socio-economic systems at global and local levels. The interactions arising at the interface between mining operations, the environment, and host communities, are inherently complex and dynamic. Notably, mining operations have large and evolving footprints along their entire life cycle. Because these mine, environmental and community interactions are not yet comprehensively understood and addressed, the mining industry's reputation has been compromised, and there is a profound "trust-gap" in the public perception of mining.

We propose that Systems Thinking and System Dynamics (SD) are particularly well adapted to address some of the crucial challenges faced by the resource sector in the 21st Century. Not only can they help understand and represent the relevant complex causal relationships to enhance mine planning at the operational level, but SD models can also be used to facilitate communication and collaboration between stakeholders with very different mental models, enriching decision-making through different and better informed perspectives (Bosch et al., 2007). A research initiative recently launched at the SMI is building the first models to explore the interrelated economic, technical and social dynamics in mining. The two following challenging issues, studied under this initiative, serve as a case in point of the relevance of using system dynamics in this context:

a) 90% of operations processing gold worldwide use cyanide leaching to recover the precious metal. Though mostly well managed in large operations, this process often triggers public concern because of its potential to contaminate water systems and cause direct and indirect impacts on biodiversity and communities. Using a System Dynamics modelling approach, the study explores the causal relationships between cyanide gold leaching, environmental contamination, community health and safety, and public acceptance.

The model developed follows the usage of cyanide from the leaching process to its disposal to tailings, including controlled releases of treated water into the environment. The potential for leakages or spill incidents to occur along the operational chain is modelled using probability distributions (such as the binomial distribution), which are influenced by factors such as the quality of maintenance and the degree of compliance to local and national regulations.

Community health and safety and community and public support are represented by stocks which have the potential to influence positively or negatively the smooth continuation of mine operations. These stocks are, therefore, connected back to the amount of gold ore processed per year, creating the main balancing feedback loop of the model.

b) The irregular booms and busts inherent to the mining industry are determining investment patterns and provoke substantial social risks. In particular, they can impact on the expansion of the mine footprint and the necessity to displace people, sometimes on multiple occasions. In this study we explore the dynamic relations between commodity market price, operations expansion, the number of economic and physical displacements, and the impact on communities' livelihoods.

The approach taken in this model analyses the distance between operations and human settlements coming from infrastructure expansions and in-migration. Shortened distances and higher population density are expected to increase the 'nuisance' factor and social risks (environmental safety, likelihood of conflict) and trigger necessity for relocation and resettlement.

Especially in the context of a developing country, the community sense of trust and support in this model is expected to follow an "overshoot and collapse" type of dynamic behavior. The arrival of a large mine operation is often seen as a major economic and development opportunity, but inadequate planning of resettlements can lead to very complex and entangled issues (Owen et al., 2019).

The objective of this project is to create models that will be refined according to a range of specific real-life case studies. Therefore, one of the main challenges is to articulate the problems and structure the models in a definite but adaptable way.

These two examples of System Dynamics applied to the mining industry reflect some of the dynamics that should be encompassed in mine business planning over the entire life mine cycle. By doing so, the resource sector, which has a great potential to contribute to achieving the Sustainable Development Goals (SDGs) (UNGA, 2015), would be in a better position to supply the metals needed for transitioning to fossil-free energies, while providing lasting value to socio-economic well-being for host countries and communities.

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