

Broadening our Understanding of ASM Sustainability Complexity: A Systems Thinking Lense

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Broadening our Understanding of Artisanal and Small-Scale Mining Sustainability

Complexity: A Systems Thinking Lens

ABSTRACT

Artisanal and Small-Scale Mining (ASM) is an important, growing component of the global economy. This industry creates livelihoods for people with limited alternative income generating opportunities and has the potential to retain a large share of generated wealth in the national economies where it exists. However, ASM has potential negative social and environmental impacts that are quite significant. This combination of characteristics makes ASM a complex system whose efficient regulation requires more than event-oriented policy interventions, but regulatory approaches that are informed by holistic and systemic views. Regulatory history in ASM has shown that each time politicians and regulators attempt to proffer well intentioned interventions, unintended consequences are often the result. This study attempts to amplify the relevance of applying systems thinking tools in improving our understanding of ASM sustainability. The enhanced understanding brought about by a model-based-systems thinking approach applied in this study, will hopefully, aid policy makers, regulators, civil society groups and other stakeholders to adopt a holistic approach in fostering sustainable development in ASM.

Key words: Artisanal and Small-Scale Mining, Sustainability, Formalization, Systems Thinking, Objects Processes and Methods.

INTRODUCTION

ASM is an activity whereby millions of people from low-income economies, globally are involved in low-tech, labor-intensive mineral extraction, processing and marketing, largely conducted in an informal way (Fairtrade Foundation and Alliance for Responsible Mining, 2011; Gavin Hilson & Hilson, 2015). As at 2014, researchers estimated that 20 to 30 million people are directly involved in ASM in over 80 countries, and a further 75 to 125 million people benefit indirectly from ASM for their livelihoods (Buxton, 2013; Verbrugge, 2014). ASM tends to be focused on precious stones like diamonds and precious metals like gold. In gold mining only, the ASM industry represents an estimated 10 to 15% of annual global gold production (Telmer & Veiga, 2009). While clearly providing an economic income to people living at the base of the pyramid (Prahalad & Hart, 2008), ASM often leaves behind itself a trail of serious social and environmental damage. The environmental damage from ASM is often characterized by land degradation, deforestation, river siltation, water contamination and mercury toxicity (Telmer & Veiga, 2009; UNEP, 2013). Negative social impacts emanating from ASM include exploitation of child labor, gender-based violence and disruption of community structures (Buxton, 2013; Rustad et al., 2016). Maximizing gains while minimizing negative impacts of ASM forms a complex sustainability problem that research has struggled to solve over the years (Siwale & Siwale, 2017).

The mining industry has in recent decades made significant strides in mitigating most of the negative impacts of mining but focus and success has manifested mainly in Large Scale Mining (LSM). Sustainability studies, particularly from stakeholder theory, confirm this skewed development by citing how corporates are the only entities with the capacity to meet sustainability goals (Hart, 2005). Apparently, stakeholder theory still needs to develop and cover sustainability attainment in economic spaces where corporates do not exist. The absence of formal companies

among ASM actors creates a phenomenon in which the question on how sustainable development targets can be achieved in an economic space with no corporate remains unanswered (Hennessy, 2015). This drives me to ask the question, ‘How can sustainable exploitation of natural resources be achieved in an economic environment that lacks structures of a formal organization? Attempts have, over the past two decades been made to address this question but no significant progress has so far been made (Persaud et al., 2017; Siwale & Siwale, 2017). Nonetheless, this is a broad question that I will not be able to completely answer in this paper alone. This paper will approach this sustainability question from a methodological viewpoint and as a first step I will ask, “Can model based systems thinking tools help capture interactions between business, society, economy and nature for informed sustainability management decisions?”

I view the complexity of ASM sustainability as a case of systems theory, seeing the numerous interconnected elements involved (Sterman, 2000). Nonetheless, I do not endeavor to examine how systems theory interprets the phenomenon at hand but rather how systems theory tools (systems thinking) can be suitable in solving the ASM sustainability challenge. Finding support from Holling (2001), I argue that systems thinking is the most applicable and suitable approach to the understanding of the complexity raging among most economic, social and ecological systems. Maguire et al. (2006), (2011) & Walker and Salt (2006) described such complex systems as sets of interconnected elements whose behavior follows certain governing forces. The application of systems thinking enables sustainability management researchers to “identify points at which a system remains capable to accept positive change and points at which it becomes vulnerable” (Holling, 2001). Such recognition follows the inextricably intertwined and interconnected nature of relationships among elements at the interplay of ASM practice and sustainability. These

connections together form a chain of complex systems whose properties are more than sums of the individual components. Hence, the need for an inter-disciplinary dynamic approach.

This study is one step towards deeper understanding of various dynamics at the interplay of mineral exploitation and sustainability in ASM contexts - where no company exists (Hennessy, 2015). The study attempts to add its voice to an emerging field of research in which systems thinking is becoming recognizable as an applicable and suitable tool for modelling complex socio-economic phenomena. The application of systems thinking into simulating sustainability in mining has seen little research being done over the years. Of the few studies in this field are the works of Alaoma & Voulvoulis (2018); Lagnika et al (2017); Maluleke & Pretorius (2013); O'Regan & Moles (2001), (2006) who looked into impacts emanating from various environmental, economic, corporate and governmental policies on the mining industry and the interactions among those policies. In particular, among the available systems thinking tools, these researchers used Systems Dynamics Modelling Simulation in their studies (Moon, 2017 & Lagnika et al., 2017). In addition, Nageshwaraniyer et al. (2011) also applied Discrete Event Modelling Simulation in optimizing operational decisions for mining activities by making use of real time information obtained from field sensors that were connected to an Enterprise Resource Planning system. Nonetheless, as argued by Hennessy (2015), largely, the hype behind sustainable mining emphasizes best practices by taking a spatial and temporal framework that is predominantly applicable to large-scale, advanced formal mining companies. Such an approach obscures individual miners' (ASM) production from mainstream debates on sustainable mining and indigenous rights.

This study managed to apply a model-based systems thinking methodology and flesh out the ASM-sustainability system and laid bare the various connected elements often overlooked by policy

makers when attempting to foster sustainability through in ASM. Further to identification of involved elements, the created models provide improved understanding of the system. Nonetheless, this study does not go as far as quantifying the various system elements but acts as a conceptual level basis for further critical analysis of ASM formalization and subsequent sustainability dynamics.

THEORETICAL PERSPECTIVES AND PAST STUDIES

On several occasions, researchers have questioned the use of simple, straight forward models that assume linear progressions of well-defined event stages leading to well-defined outcomes (Schwenk, 1985; Van De Ven & Polley, 1992). After a few divergencies from such linear approaches (Mintzberg et al., 1976; Nutt, 1984), researchers have increasingly expressed acknowledgement that multi-layered and dynamic contexts, multi-directional causalities, and feedback loops do exist and they often interfere with steady progression of events towards equilibrium. The eventual position taken by many scholars is that chaos theory and complexity theory possess the potential of offering a better understanding of organizational processes (Stacey, 1995; Thiétart & Forgues, 1995). However, Langley (1999) queried that disposition sighting that the specific explanatory mechanisms behind the application of complexity theory are usually not specified and the general understanding that organizational processes consist of opposing forces, feedback loops and nonlinearities needs fleshing out.

Complex systems comprise several interacting elements that organize themselves through dynamic modes, are normally unpredictable in the long-run, yet can learn from past experiences (Adam & De Savigny, 2012; Paina & Peters, 2012; Tan et al., 2005). Paina et al., 2014 further asserts that, a

research design that acknowledges complex systems' features, together with potential interactions from contextual factors is suitable to guide exploration of complex phenomena from multiple perspectives. The usefulness of such a methodological approach would be that it facilitates exploration of complex system features that include feedback, emergence, and self-organization (Paina et al., 2014). Considering the multiplicity of elements in the ASM sustainability case, I, therefore, posit that a research methodology that acknowledges complex systems' features, together with potential interactions from contextual factors is ideal for broadening our understanding and foster sustainable development.

ASM complexity

An example of ASM complexity can be obtained from the Zimbabwean ASM sector during the period between 2004 and 2008 (Appendix A). In 2005, the Government of Zimbabwe forced all gold producers to sell their gold to the national sole gold buyer, at a lower price (a fraction of the international price) and that policy pushed miners to the informal market. The miners' response, coupled with excessive environmental degradation from the sector prompted the Government of Zimbabwe to criminalise ASM and heavily crackdown on the informal market. Nonetheless, this policy intervention resulted in three unintended consequences – two of which were worsened instants of the initial problems and one which was a newly emergent problem. Total national gold output fell from as high as 22t in 2004 to about 3.6t in 2008. This does not mean, gold production in the ASM sector had stopped but rather quantities flowing informally increased. A problem of corruption emerged as lowly remunerated regulatory agents collected bribes from ASM actors and allowed irresponsible mining and informal market to grow worse. ASM actors did more harm to the environment as they needed to both pay bribes and make profits. Hence, an understanding of

the dynamism, non-linearity, feedbacks, and interconnectedness of elements in the system could have been necessary to bring about sustainable policy interventions (Dembetembe et al., 2018).

How can systems thinking help?

Systems thinking is a methodological approach useful in understanding change and complexity. By definition, systems thinking is the “ability to see things as a whole” rather than parts and subsequently finding interconnections and explaining the complexity at hand (Maan & Cavana, 2007). Under systems thinking we have Systems Thinking and Modelling (STM) which is a methodological framework based on systems dynamics, an approach first developed by Jay Forrester at the Massachusetts Institute of Technology in the 1950’s through the application of feedback control theory to simulation models of organizations (Forrester, 2003). According to Sterman (2000), STM generally models the basic structure of a system in such a way that the behavior produced by the system is captured. As a result, clear and quantitative cause and effect relationships can be given. Relationships are constructed by identifying feedback loops that exist between objects within the system. Feedbacks can be positive or negative and can as well be stock-and-flow relationships. Under such circumstances, changing one variable affects the other variables in the systems over time and in turn the original variable is affected too. By managing to identify all these relationships and correctly and explicitly interpret them, we are then able to understand complex systems.

Understanding of the dynamic interactions across interconnected systems can help address pressing societal issues like climate change, social inequality and ecological degradation (Whiteman et al., 2013). Many scholars have increasingly recognized the necessity of a systems approach in understanding the complexity of highly interdependent systems. These are instances where social

systems are embedded within natural systems thereby bringing up the dependency of business on nature (Gladwin et al., 1995; Marcus et al., 2010; Roome, 2012; Starik & Rands, 1995).

Sustainability and Systems Thinking

For some time, sustainability literature was more corporate-oriented and more focused on firm and industry effects (Whiteman et al., 2013) without radical new insights (Bansal & Gao, 2006). Against this backdrop Marcus et al. (2010); Starik and Kanashiro (2013) & Whiteman et al. (2013) argued that an isolated understanding of corporate actions without linking them to social-ecological systems may not help address interconnected sustainability challenges. Systems thinking is the solution to that problem of silos as it comes with an offer for a holistic approach to examine the role played by corporations within socio-ecological settings (Williams et al., 2017). While talking about corporations, a blind eye has for long been turned on cases “where there is no company” (Hennessy, 2015). This paper, therefore, seeks to contribute to the discussion on sustainability by introducing the angle of individual operators (ASM) within the world of natural resources exploitation.

As indicated by De Failly et al. (2013); Hilson & Okoh (2013) existing policy and regulatory responses to ASM are often incoherent, unstable, misdirected, counter-productive and in some cases even non-existent. This comes against a situation apparently calling for robust and consistent policies from governments of countries with highly pronounced ASM sectors. These countries require regulatory interventions that can maximize the benefits from ASM while minimizing the negative impacts of the industry.

The interdependency existing between organizations (in this case ASM) and the natural environment is key in systemic sustainability management since organizations rely on inputs from the natural environment while the same environment is impacted by organizational actions through feedback loops (Starik & Rands, 1995; Starik & Kanashiro, 2013). Apparently, this is an embedded view of organizations and it recognizes systemic limits to growth within planet boundaries, finite resources as well as the dependency of firms on nature, society and the economy (Gladwin et al., 1995; Marcus et al., 2010; Rockström et al., 2009; Whiteman et al., 2013; Winn & Pogutz, 2013). As a result, we arrive at the question, “Can model based systems thinking tools help capture interactions between business, society, economy and nature for informed sustainability management decisions?”

Conceptual Framework

With regards to ASM sustainability, a lot of research work has since been done and much of the work recognizes formalization of ASM as the gateway to sustainability (Siwale & Siwale, 2017). The main process for the system created in this study was formalization of ASM, the purpose of which is to foster sustainability (Siwale and Siwale, 2017). This research borrows the broad view of formalization by Heemskerk (2005) who asserted that formalization can be conceptualized as the process of registering, organizing and monitoring of mining activities in the field. Heemskerk’s definition is also echoed by Lowe (2005) who defined formalization as not only an act of legislation but an activity that proceeds to the activation and enforcement by authorities. Figure 1 presents a theoretical framework which lays out the various forces underpinning the complexity of ASM sustainability. The same conceptual framework was used in this study as basis for the development of later models as exhibited in Figures 2 to 4 in the Results section.

Insert Figure 1 about here

This study, therefore, seeks to create a system that formalizes ASM thereby creating a conducive environment for sustainable behavior among players. The system functions by optimizing the regulatory practice born from the available mining policy. Enablers for this function would include a systems thinking model, policy makers, regulators and the society. Environmental factors surrounding the formalization process include the society and the natural environment that tends to be affected by ASM activity. Lastly, the problem being solved by the system is irresponsible behavior by ASM. Table 1 presents the elements of the system and the various literature sources from which they were drawn.

Insert Table 1 about here

This article proceeds by presenting an opportunity for systems thinking researchers to explore applicability of model-based systems thinking techniques to deepen our understanding of interactions at the interplay of natural resources exploitation and sustainability. First, the article presents a three-step methodology followed in modelling identified aspects of ASM formalization. Secondly, the article outlines the results in the form of systems thinking models that were created. Lastly, a discussion of the usefulness of model-based systems thinking in understanding ASM sustainability is made at the same time opening directions for future research.

METHODOLOGY

Variables

Despite substantial focus on sustainability in both science and politics, society remains haunted with persistent poverty and inequality while the environment continues to suffer ecological damage (Fischer et al., 2007). Of course, already in use are several policy tools including Agri-environment schemes, pollution regulations or markets for emissions trading. On top of that, corporate social and environmental responsibility is increasing in most industry sectors. In mining, for instance there is ‘Fairmined’ and ‘fairtrade’ (Sippl, 2015). All these initiatives seem to struggle to bring us the light of the day. Hence, I argue that the transition from the current ASM sustainability trend to a truly sustainable path calls for a new policy formulation methodology. Subsequently, I declare my *dependent variable* in this study as, ‘effective mining policy formulating strategy for sustainability achievement.’ Such a successful policy making strategy will depend on numerous *independent variables* that include system purpose, function, enablers and environmental forces (Dori, 2011).

Sample and Databases

All modelling processes were carried out following conceptualizations of the ASM industry from various literature sources collected from six databases: ScienceDirect, Taylor & Francis online, Wiley & Son, Elsevier, Springer and Google scholar (Table 1). Literature aided in the identification of elements in the form of objects and processes that had to be included in the OPM modelling process. A system diagram in OPM includes the main process, the purpose, the function, the enablers, the environment, and the main problem that the system is attempting to solve. Reviewing about 108 literature sources (20 of which were the most useful) on ASM formalization yielded these parameters as respectively displayed in Table 1.

The modelling Process

There are numerous simulation methods that have been applied in simulation for sustainability, the most common ones being Agent-Based Modeling and Simulation, Discrete- Event Modeling and Simulation, and System Dynamics Modeling and Simulation (Moon, 2017). This paper adds to that collection by applying a Model Based Systems Engineering (MBSE) simulation approach. The various simulation methods make use of a wide range of software applications such as Vensim, Arena, NetLogo, Powersim and Stella (Moon, 2017). While all these software packages are good, this study makes use of Objects Processes and Methods (OPM) developed by Dori (2011) as a methodology and language for conceptual modeling of systems used in MBSE. OPM was chosen and applied in this research for three main reasons: It is ISO certified (ISO 19450) and an increasing number of Fortune 500 companies make use of this method; it makes use of a simple Object-Process Diagram that runs through an Object-Process Language (OPL) which is a subset of English and finally that it is domain independent. Consequently, OPM can facilitate communication and shared understanding among all the system stakeholders (Dori, 2011).

The modelling process was done in three stages namely, creation of the first level System Diagram (SD), in-zooming (uncovering the contents of the main process) to create the expansion of the main process resulting in the second level system diagram (SD1) and finally combining SD and SD1. The codification of SD and SD1 was done to produce a more concise and yet fully representative model that is simple for stakeholders to understand.

RESULTS

Modelling the first level SD

The starting point in the modelling process (Figure 2) was identifying the main process which in this case was formalization of ASM. As per OPM principle, the next step was identifying the purpose of the model which happened to be the fostering of ASM sustainability. ASM sustainability exhibits the miners' group and ASM sustainability can either be in a state of being sustainable or unsustainable. This relationship is expressed by the in-out pair link in Figure 2. The main function of the model is to enhance regulatory practice which is exhibited by the mining policy. The mining policy has three sub-units namely systems thinking model, policy makers group and regulatory agents' group. As per OPM principle, the sub-units are connected to mining policy through an aggregation participation link. Further, regulatory practice can be either promoting or inhibiting as reflected on the two states of regulatory practice in Figure 2. The enablers of the systems were identified as a set of three instruments (systems thinking model, good regulatory practice and society) and two agents (policy makers group and regulatory agents' group). The problem that the model is trying to solve is irresponsible behavior in ASM which when regulatory practice is inhibiting can result in an unsustainable ASM sustainability state. Lastly, the environmental spheres of the model have miners and the natural environment. Society and the natural environment are affected by both irresponsible ASM behavior and formalization. The OPL in Appendix B gives a description of each link used to join the various objects and processes in Figure 2.

Insert Figure 2 about here

Modelling the second level SD (SD1)

As explained under the methodology section, using the in-zooming process of OPM, I modelled the SD1 for the ASM formalization process. The formalization process is a synchronous process meaning a process in which formalization sub-activities occur in a defined sequence. This research borrows the broad view of formalization by Heemskerk (2005) who asserted that formalization can be conceptualized as the process of registering, organizing, and monitoring of mining activities in the field. Heemskerk's definition is also echoed by Lowe (2005) who defined formalization as not only an act of legislation but an activity that proceeds to the activation and enforcement by authorities. Hence, as shown in Figure 3 SD1 attempts to further dissect the inner dimension of the formalization process which in this case contains registering, organizing, and monitoring. The three sub-processes are linked to an ASM condition representation that tends to change from an illegal condition to a point of responsible behavior as the formalization process proceeds. The relationship between each formalization stage and the various states of ASM condition representation are shown in the OPL in Appendix C. Noteworthy, registering changes ASM condition from illegal to illegal; organizing changes ASM condition from just being legal to being organized and monitoring takes ASM condition from being organized to being responsible. Finally, monitoring also changes sustainability level of ASM from unsustainable to sustainable.

Insert Figure 3 about here

Figure 4 is the final systems thinking model for this ASM formalization process. In this model, the new object (ASM condition representation) formed through the in-zooming process is added to the original (first level) SD. To avoid having a model which is too complex to read and understand,

the whole in-zoomed process is not included but just the new ASM condition representation. The ASM condition representation is also not wholly included but the various states are suppressed as indicated by the box with three dots at the bottom of the respective object. As an OPM principle, the new ASM condition representation is joined to the main process with an ‘affect link’ which in principle is a link that shows that the two items affect each other. Lastly, an exhibition characterization link joins the ASM condition representation to the systems thinking model which in essence is the tool that provides insight into the effects that every process has on the overall goal of improving sustainability.

Insert Figure 4 about here

DISCUSSION

While ASM has the potential to create livelihoods for people with limited alternative income generating opportunities and has the potential to retain a large share of generated wealth in the national economies where it exists, the industry has potential negative social and environmental impacts that are quite significant (O’Faircheallaigh & Corbett, 2016). This combination of characteristics makes ASM a complex system whose efficient regulation requires more than event-oriented policy interventions, but regulatory approaches informed by holistic and systemic views (Dembetembe et al. 2018). Regulatory history in ASM has shown that each time politicians and regulators attempt to proffer well intentioned interventions, unintended consequences are often the result. Hence in this study, I questioned, “How can sustainability be achieved in a complex scenario characterized by significant natural resource exploitation benefits from individual players yet

shadowed with numerous negative environmental and social impacts.” As a follow up question, I desired to know, “Can systems thinking help?”

The systems thinking model created in this study attempts to bring out the different ASM system elements and display how they are interconnected. The idea behind systems thinking is to promote holism (Sterman, 2000) as oftentimes, crucial elements necessary for regulation and decision making are omitted and not only that but the understanding of the relationship between elements is often poorly understood. Furthermore, since a multi-stakeholder approach is necessary and is particularly key with regards to the planning for formalization as well as the design of legislation (Hilson, 2009), legislation must, in turn, specify parties responsible for the implementation, supervision and management of different formalization aspects so as to facilitate effective coordination between stakeholder groups (Keller et al., 2014; UNEP, 2012). Such clarity of purpose and direction is what the systems thinking model provided in this research supply. From the model, the different parties have been identified as enablers and in particular, policy makers, regulators, and society. The parties also have to work with assistance from a technical instrument herein stated as a systems thinking model.

On the other hand, the model presents society as an instrument for the formalization process (Appendix B). Observed from another angle society should rather affect and be affected by the formalization process. This is also perfectly correct, but it should be noted that both perspectives are applicable as society is passively or sometimes actively used by agents in the formalization process. For instance, farmers consent to the registration of mining claims within their farms. In this way society is used to promote formalization without it being the instigator of formalization. Apparently, it means society can be associated with the formalization process by either an ‘affect

link’ or ‘instrument link.’ The former tends to be all encompassing while the latter is specific. It remains the same with possibly many other elements in the model but at the end of the day, “all models are wrong, but some are useful” (Box, 1976).

In defining the ASM sustainability systems, I acknowledge that the system can grow bigger than portrayed in this study. First of all, sustainability in mining involves at least five dimensions namely economy, society, environment, safety and resource efficiency (Laurence, 2011). This study, however, does not explicitly include all dimensions but limits itself to economic and social sustainability. Although this can be a valid argument, I continue to argue that once the problem of irresponsible ASM behavior is solved by an all-encompassing regulatory framework (Figure 4), sustainability will be achieved. Secondly, the model created does not explicitly spell out who is in society or rather which stakeholders are involved. Considering that, I admit that expounding society may reveal other stakeholders, for instance, civil society organizations who are in essence, active agents of formalization. Nonetheless, all stakeholders only feed into the mining policy development but do not practically carry out regulatory or legislative functions. It, therefore, remains that the created model can function as it is and further unfolding it would only make it complex and difficult to understand.

As a limitation, the model presents miners as ‘informatical’ meaning they are not a physical entity but rather an element in the information and communication technology realm. This is not true as we know miners to be people involved in the mineral extraction business. This is, therefore, an error made by the modelling tool because it understands miners in the sense of ‘data mining.’ Nonetheless, the error must not have dire consequences as long as anyone reading the model is made aware of how it got generated.

Future directions

Contrary to commonly used assessment methods, systems thinking can perform simulation and quantification of the behavior of dynamic systems. In this paper, I attempted to simulate the formalization process of ASM without necessarily quantifying and observing how involved system dynamics behave. While I admit that the simulation process might still need further improvements at the conceptual stage, future research can go further to focus on the quantification of system elements. Lastly, as Box (1976) said, “all models are wrong, but some are useful.” It, therefore, follows that the model developed for ASM formalization for improved sustainability, in this study, is never the absolute and none can be absolute, neither. Further research using either OPM or other simulation methods must continue with refined practice to model similar systems with clear objectives, explicit assumptions, clear study limitations and clearly articulating insights discovered.

Study implications on practice

The implication is that the model acts as a blueprint of the system. The model is the source of authority whose function is to enable all parties involved to be on the same page every time and OPM is more suitable for displaying overall system picture (Grobshtein et al., 2007). Nonetheless, the conceptual model is not the final stage but rather one step into a lifecycle of the system. Lifecycle refers to the stages that the system undergoes as it develops from problem definition, needs assessment and modeling, evaluation of concept, architecting, detailed design, all the way to the implementation stage. In this particular research, the goal was to just stress that a systems thinking model can be a useful tool that prevents potential misunderstandings and future problems with system development.

Thus, as applied in this paper, MBSE demonstrated the usefulness of systems thinking models in providing better understanding of phenomena. The MBSE is a methodology used to design systems based on conceptual models. Designed models represent the system at various levels of complexity and do evolve during the system's lifecycle stages. Such a conceptual model enables system developers together with other various stakeholders of the system to have an in-depth understanding of the system and be able to communicate with each other in a clear and efficient manner. For instance, miners have been identified as environmental objects, meaning they do not initially play an active role in fostering sustainability but do wait for a conducive regulatory framework which enables the conversion of their status from illegal to responsible (Figure 3).

The aim of this research was to provide understanding of organizational phenomena through the provision of a “vicarious experience” of a real world experience in the fullness of its richness and complexity (Lincoln, Y.S., Guba, 1985). Regarding understanding of theories, Langley (1999) asserts that simple theories which carry substantial explanatory capacity are mostly preferred to complex ones which could be explaining a little more. It therefore, follows that good research is more like a poem than a novel (Daft, 1983). The systems thinking approach and the systems thinking model developed in this paper tried to represent the complex ASM sustainability phenomenon in yet a simple and understandable way. As an answer to the question asked at the beginning, understanding sustainability complexity in a field with no formal organizations can be enhanced by modelling the system using a method that recognizes the purpose, function, enablers, environment, and problem occurrence. Subsequently, these aspects can be further fleshed out if need be. Systems thinking tools as exemplified by OPM, a model-based simulation method applied in this paper can help realize this broadened understanding of phenomena.

CONCLUSION

This paper acted as the first step into ASM sustainability issues modelling with OPM as a systems thinking tool. The conceptual model created provided a broadened understanding of various issues that all stakeholders need to be conversant with when approaching formalization. This study adds voice to the growing appreciation of the relevance of applying systems thinking skills in improving our understanding of socio-economic systems. The enhanced understanding brought about by a model-based-systems thinking approach applied in this study, will hopefully, aid policy makers, regulators, civil society groups and other stakeholders to adopt a holistic approach in fostering sustainable development in ASM and in similar contexts.

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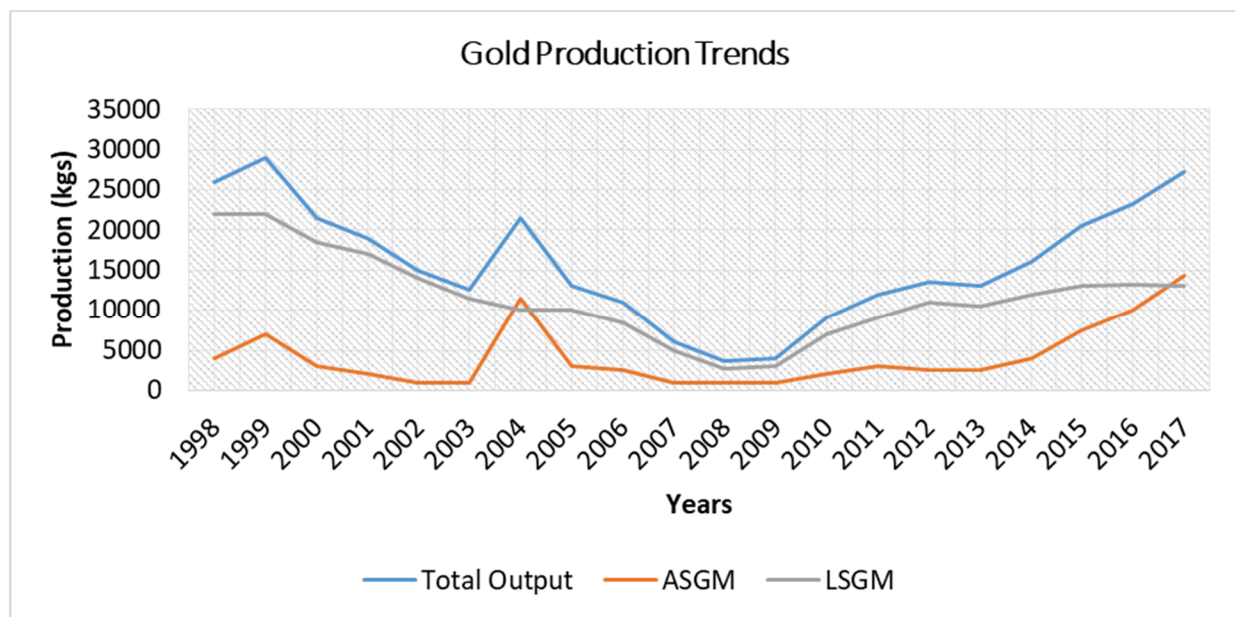
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APPENDICES

APPENDIX A: Zimbabwean gold production trends for both ASM and LSM for the period 1998 to 2017 (Chamber of Mines of Zimbabwe, 2016; RBZ, 2016 & ZMF, 2018).



APPENDIX B: An OPL for SD indicating the interpretation of all connections among the objects and processes in SD (own illustration)

OPL

Mining Policy is informatival and systemic.
 Systems Thinking Model is informatival and systemic.
 Policy Makers Group is informatival and systemic.
 Regulatory Agents Group is informatival and systemic.
 Regulatory Practices of Mining Policy is informatival and systemic.
 Regulatory Practices of Mining Policy can be promoting or prohibitive.
 Society is informatival and systemic.
 Natural Environment is informatival and environmental.
 Asm Sustainability of Miners Group is informatival and systemic.
 Asm Sustainability of Miners Group can be sustainable or unsustainable.
 Miners Group is informatival and environmental.
 Miners Group exhibits Asm Sustainability.
 Mining Policy exhibits Regulatory Practices.
 Mining Policy consists of Policy Makers Group, Regulatory Agents Group, and Systems Thinking Model.
 Formalising Asm is informatival and systemic.
 Formalising Asm changes Asm Sustainability of Miners Group from unsustainable to sustainable.
 Formalising Asm changes Regulatory Practices of Mining Policy from prohibitive to promoting.
 Formalising Asm requires Policy Makers Group, Regulatory Agents Group, and Systems Thinking Model.
 Formalising Asm affects Natural Environment and Society.
 Irresponsible Asm Behavior is informatival and systemic.
 Irresponsible Asm Behavior affects Natural Environment and Society.
 Irresponsible Asm Behavior consumes Regulatory Practices of Mining Policy at state prohibitive.
 Irresponsible Asm Behavior yields Asm Sustainability of Miners Group at state unsustainable.

APPENDIX C: An OPL for SD1 indicating the meanings of the various connections among objects and processes in SD1(own illustration)

Asm Sustainability of Miners Group can be sustainable or unsustainable.

Miners Group is informatical and environmental.

Regulatory Practices of Mining Policy is informatical and systemic.

Regulatory Practices of Mining Policy can be prohibitive or promoting.

Mining Policy is informatical and systemic.

Systems Thinking Model is informatical and systemic.

Natural Environment is informatical and environmental.

Society is informatical and systemic.

Policy Makers Group is informatical and systemic.

Regulatory Agents Group is informatical and systemic.

Asm Condition Representation is informatical and systemic.

Asm Condition Representation can be illegal, legal, organised or responsible.

Miners Group exhibits Asm Sustainability.

Mining Policy exhibits Regulatory Practices.

Formalising Asm is informatical and systemic.

Formalising Asm affects Natural Environment and Society.

Registering is informatical and systemic.

Registering changes Asm Condition Representation from illegal to legal.

Registering requires Policy Makers Group, Regulatory Agents Group, and Systems Thinking Model.

Registering consumes Regulatory Practices of Mining Policy at state prohibitive and Asm Sustainability of Miners Group at state unsustainable.

Organising is informatical and systemic.

Organising changes Asm Condition Representation from legal to organised.

Organising requires Policy Makers Group, Regulatory Agents Group, and Systems Thinking Model.

Monitoring is informatical and systemic.

Monitoring changes Asm Condition Representation from organised to responsible.

Monitoring requires Policy Makers Group, Regulatory Agents Group, and Systems Thinking Model.

Table 1: System features for the modelled process and the actual identified elements based on literature (own illustration)

<i>System Feature</i>	<i>Identified actual ASM element</i>	<i>Sources</i>
<i>Purpose</i>	Sustainability – the system aims to improve the sustainability of the ASM industry.	(Gavin Hilson et al., 2018) (Gavin Hilson & Murck, 2000) (P. Ledwaba & Nhlengetwa, 2016) (Salo et al., 2016) (Sinding, 2005) (Verbrugge, 2015) (Zvarivadza, 2018)
<i>Function</i>	Regulatory Practice – the system functions by changing the regulatory practice resulting from the mining policy.	(Keller et al., 2014; UNEP, 2012) (Collins & Lawson, 2014) (Hentschel et al., 2002) (Gavin Hilson, 2009) (Gavin Hilson, 2020) (P. F. Ledwaba & Mutemeri, 2018) (Siwale & Siwale, 2017)
<i>Enablers</i>	<i>Systems thinking model</i> – this is an ‘informatical’ tool for assessing different policy positions. <i>Policy makers</i> – these are elected official responsible for making laws governing ASM. <i>Regulatory agents</i> – these are agents of the government responsible for implementing mining policies. <i>Society</i> – these are people living in ASM vicinity including those whose activities are directly or indirectly connected to ASM.	(Gavin Hilson, 2009; Spiegel, 2012; Tschakert, 2009) (Fold et al., 2014) (Gavin Hilson & McQuilken, 2014) (P. Ledwaba & Nhlengetwa, 2016) (Mutemeri et al., 2016) (Spiegel, 2012)
<i>Environment</i>	Society – these are people living within ASM vicinity as well as stakeholders in the upstream ASM processes. Natural environment – this is the collection of the biotic and abiotic spheres around mining communities.	(Kambani, 2003; Masealeti & Kinabo, 2006; Shoko & Mwitwa, 2015) (Dreschler, 2001) (Hentschel et al., 2002) (Gavin Hilson, 2009) (Gavin Hilson, 2002) (Spiegel & Veiga, 2005)
<i>Problem Occurrence</i>	ASM behavior – this refers to the conduct of ASM with regards to ESG issues.	(Siwale & Siwale, 2017) (Dreschler, 2001) (Fold et al.,

2014) (Salo et al.,
2016)(Seccatore et al., 2014)

Figure 1: Theoretical framework showing the various elements forming the ASM system and how they are connected (own illustration)

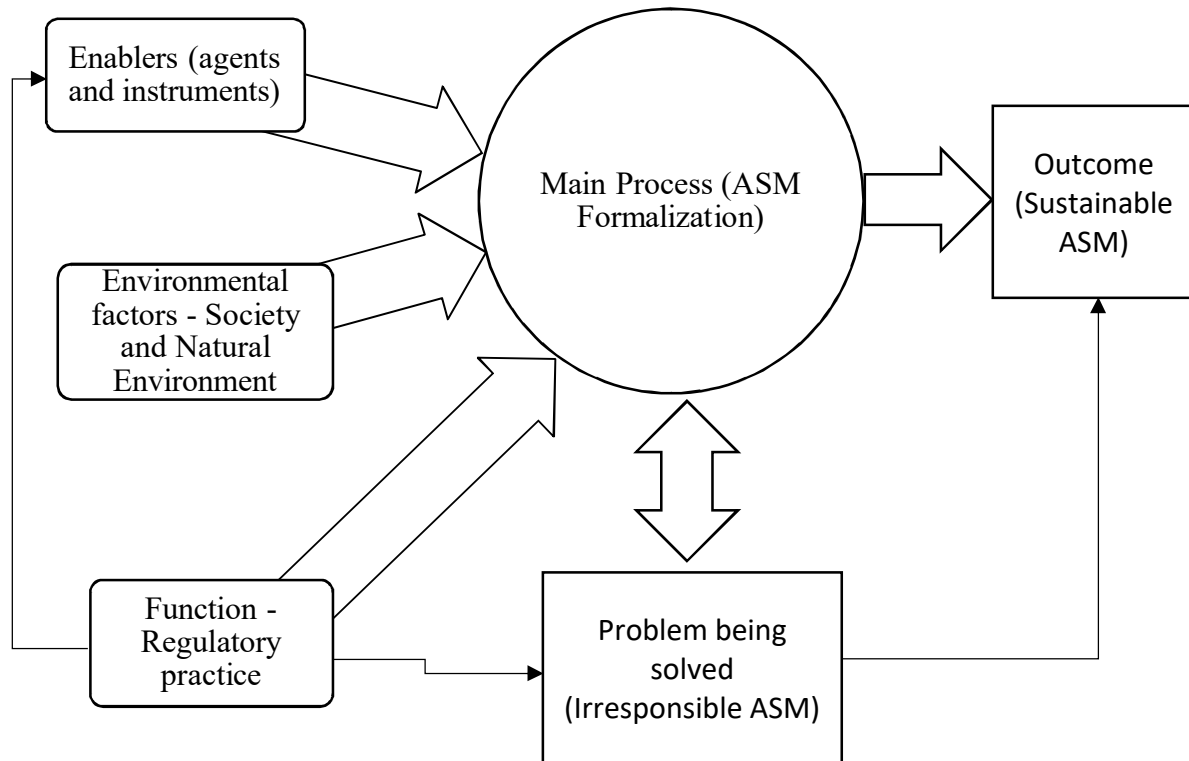


Figure 2: First level system diagram showing the main process, system purpose, function, enablers and environmental objects (own illustration)

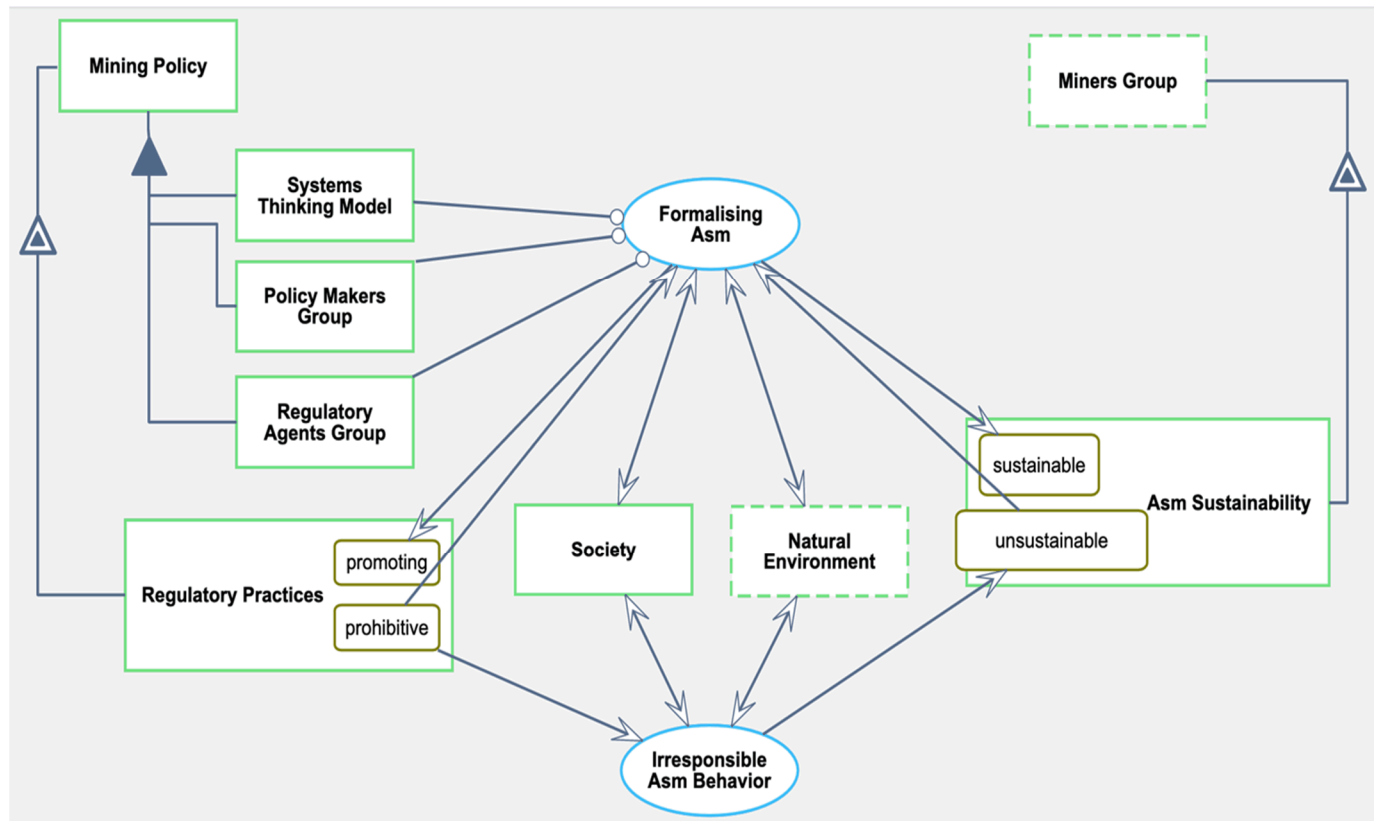
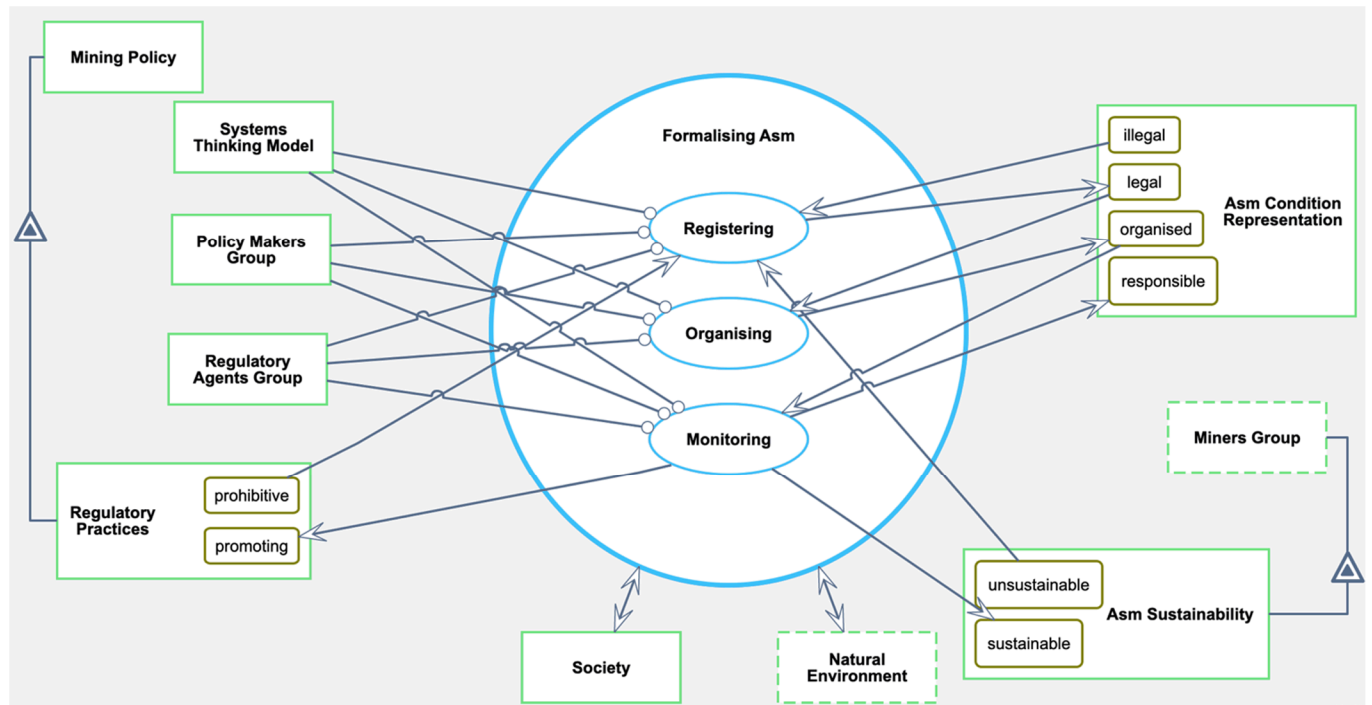


Figure 3: The in-zoomed system diagram (SD1) showing the synchronous stages of the main process and the ASM condition representation (own illustration)



with the systems thinking tool (own illustration)

