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Engineering complex systems applied to risk management in the mining industry

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ABSTRACT

Related to complexity, there is a wide diversity of concepts, ranging from "systemic" to "complex", implying a need for a unified terminology. Per different authors, the main drivers of complexity can be found in human behaviour and uncertainty. This complexity, structural or dynamic can be organizational, technological, or nested in their relationship. ISO international standard 31000:2009 definition of risk management "coordinated activities to direct and control an organization with regard to risk", when applied to economic sectors, industry, services, project, or activity, it requires the use of models or theories as guidelines. Therefore, as its basic elements comprehend human behaviour and/or uncertainty, risk management to be effective and adapted as much as possible to reality, must be operational within complex systems, as already demonstrated in different R&D environments. Risk management faces demanding challenges when approaching specific and endogenous needs, such as the mining sector. This paper presents a multivariable function analysis methodology approach based on complex system modelling and through real data corresponding to a risk management tool in the mining sector.

1. Introduction

Currently risk management is perceived as a tool for any business sector. In an economy of global scale and high volatility due to uncertainty of the markets, risk management is critical for decision makers to obtain high productivity gains.

In certain industries, risk management should be given careful attention due to the potential impact of project failure on public safety or the environment, e.g. in the mining sector due to risk perception, feasibility decision making and uncertainty.

Traditional risk management systems tend to lack full response to the specific challenges of the mining industry e.g. human capital, climate changes and new technologies. In this sense, new approaches must be found to obtain an overall answer. In a technology transfer offshore wind energy project, there was evidence, that complex systems are well-adapted models for risk management.

Technical and socioeconomic complexity and organizational culture are amid the main characteristics of complex systems. In the same sense, the mining sector is in its nature complex, encompassing major hazards, socioeconomic impacts, and resource nationalism.

International Labour Organization Convention concerning Safety and Health in Mines establishes "that workers have a need for, and a right to, information, training, and genuine consultation on and participation (...) concerning the hazards and risks they face in the mining industry".

Mining is a complex system, as it includes human, organizational, and technological issues.

In such context, risk assessment of integrated operations, can be improved by complex risk models and dynamic environments. Hence, complex systems can provide decision makers a supporting tool comprising a three axes analysis model. Each axis (X, Y and Z) comprehends a multivariable function (f_i): X: (f_1) (management variables related to mining); Y: (f_2) (risk management systems variables) and Z: (f_3) (complex systems variables). Such a proposal comprehends designing, developing, and testing a risk management decision making model within complex systems, transversal to other hazard sectors of economic activities. Validation through real data may provide organizations with sustainable and integrated risk management indicators.

2. Method

The review for the present paper is mostly based on several resource databases and scientific journals through Exlibris Metalibis. Research was conducted related to three main topics, that is,

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Table 1
Objectives of complex thought.

ID	Description
1	Understand and learn to live with uncertainty
2	Learn to deal with paradoxes and situations that cannot be solved by the binary logic
3	Provide people more thinking flexibility
4	Understand life better, nature systems and man-made systems
5	Provide people a better relation in the natural world
6	Understand the ego better and learn how to deal with it in a less self and hetero destructive mode

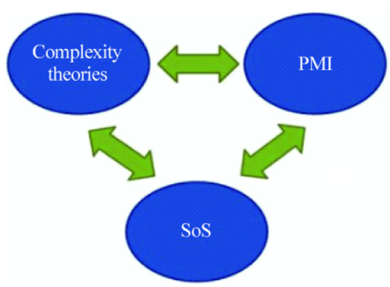

Fig. 1. Representation of the schools of complex thought [5].

risk and risk management, complex systems, and mining industry. Also, a brief understanding of the theory of complex systems through literature review on the field is presented. A systematic approach is intended with the resulting topics: complex though, complexity as a diversity of concepts, complex systems and complex projects and risk management within complex systems. To support the presented algorithm with multi variable functions and modelling, mathematical references were also used. Published case studies and previous research works are included in the review procedure, namely the published offshore wind energy project.

3. Literature review

3.1. Complex thought

Complexity thought can be defined as "more a way of thinking about the world than a new way of working with mathematical models" [1].

Complex thought is an instrument of change and resilience and it is a method in the sense of Descartes and its main objectives are embodied in Table 1 [2].

The dimensions of the complex thought are structural complexity, uncertainty, and socio-political environment and in a dynamic, ever-changing, and multi way world, in contrast to human mental models support decisions, making processes normally tied, conservative and narrow-minded and "like organisms, social systems contain intricate networks of feedback processes, both self-reinforcing (positive) and self-correcting (negative) loops" [3,4].

Today complex thought is gathered in three schools: Complexity Theories School, Project Management Institute School, and System of Systems School [5]. The Complexity Theories School comprises complexity, adaptive self-organization, co-evolutionary, social organizational, contingency, constraints, systems, network theory, nonlinearity and chaos. The Project Management Institute (PMI) School focuses on structural complexity, uncertainty, and socio political complexity dimensions. The School of System of Systems (SoS) emphasizes autonomous and independent systems, and the problem of not being capable to control them. A diagram of such relations is shown in Fig. 1, with different characteristics according to Table 2.

3.2. Complexity as a diversity of concepts

Complexity is far from being a simple concept or a single point of view; from the Santa Fe Institute, "systemic" designation, through the Morin's "complex" classification, to the need of a unified terminology claimed by Mariotti, complexity overlaps multiple labels and approaches [6,7]. Complexity must be perceived as a fabric of heterogeneous inseparable associated constituents when trying to understand complex and complexity [6]. In general complexity is defined in terms of potential states in a system or the number of components and what is particularly important to identify, is the origin of complexity, its level, and its implications [4,8].

As noted in Fig. 2, the diagram shows the main impediments to learning. Arrows indicate causation.

Complexity within collaborative design includes the interaction of many participants, working on different elements of the design, such as in diverse economic activity sectors e.g. mining sector [9]. Human behaviour and uncertainty are the touchstone to complexity basic research as established by many authors.

3.3. Complex systems and projects

In physical sciences when joining or connecting many systems, the macroscopic or collective properties of the outcoming system are not generally related with the properties of their individual constituents. In this case, the resulting system is a complex system. A complex system implies software, cultural and political issues and obviously, people and organizations that are able to affect the whole or a part of a system [10].

The more complex a system is, the more controlled must the local environment be and knowing the nature and shape of complex systems in organizations can be an important tool for the managers [11,12]. Each different context, simple, complicated, complex, chaotic, requires different managerial response [1]. Such is the case in "soft" systems thinking, better adequate to fuzzy ill-defined situations when people and cultural background are concerned [13].

Organizational behaviour and individual's emotional intelligence may support studies concerning the complex interconnection between individuals in an organization or a project team

Table 2
Characteristics of the schools of complex thought [5].

<table>
<tr><th>Complexity theory</th><th>PMI</th><th>SoS</th></tr>
<tr><td>Edge of chaos</td><td colspan="2">Non-linear</td></tr>
<tr><td>Tiny initiating events</td><td colspan="2">Autonomous systems</td></tr>
<tr><td>Contingency</td><td colspan="2">Flexible</td></tr>
<tr><td>Power laws and Paretian distributions</td><td colspan="2">Uniqueness</td></tr>
<tr><td>Control parameters</td><td>Difficulty</td><td>Adaptive cycles</td></tr>
<tr><td>Scale laws</td><td>Multiple stakeholders</td><td>Aren't built for the same purpose</td></tr>
<tr><td>Coarse-graining</td><td>Uncertainty</td><td>Fitness landscape</td></tr>
<tr><td></td><td>Changing projects governance</td><td>Unclear and unfixed boundaries</td></tr>
<tr><td></td><td>Technology newness</td><td>Fractals</td></tr>
<tr><td></td><td>Trust</td><td>Chaotic behaviour</td></tr>
<tr><td></td><td>Indirect communication</td><td>Share and acquisition environment</td></tr>
<tr><td></td><td>Megaprojects</td><td>Self-organization</td></tr>
<tr><td></td><td>Context dependence</td><td>Emergent</td></tr>
<tr><td></td><td>Ambiguity of features</td><td></td></tr>
<tr><td></td><td>Capability</td><td></td></tr>
</table>