

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/309513511>

# ISMS 2016 Risk Management in the Mining Sector through Complex Systems

Conference Paper · August 2016

CITATIONS

0

READS

76

3 authors:



**Sameiro Queiroz**

University of Porto

13 PUBLICATIONS 4 CITATIONS

SEE PROFILE



**Adelina Baptista**

Lusíada University

19 PUBLICATIONS 139 CITATIONS

SEE PROFILE



**Miguel Tato Diogo**

University of Porto

26 PUBLICATIONS 3 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Complex Systems [View project](#)



Photophysical characteristics of DNA–cationic vesicle interaction [View project](#)

All content following this page was uploaded by [Sameiro Queiroz](#) on 29 October 2016.

The user has requested enhancement of the downloaded file.

## Risk Management in the Mining Sector through Complex Systems

AUTHORS: Maria S. Q. Domingues<sup>a</sup>, Adelina L. F. Baptista<sup>b</sup>, Miguel T. Diogo<sup>a,\*</sup>

<sup>a</sup> CERENA – Centre for Natural Resources and the Environment, Faculty of Engineering of the University of Porto, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal

<sup>b</sup> Universidade Lusíada do Norte, Edifício da Lapa, Largo Tinoco de Sousa, 4760-108 Vila Nova de Famalicão, Portugal

### ABSTRACT

Related to complexity there is a wide diversity of concepts. What the Santa Fe Institute (USA) calls “systemic” corresponds to what Morin (Morin, 2006) calls “complex” until there is a unified terminology (Mariotti, 2000). When understanding complex and complexity, then complexity can be perceived as a fabric (what is woven together) of heterogeneous inseparably associated constituents (...) (Morin, 2006). According to different authors 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. The complex interrelationship that exists between individuals within an organization or project and its influence on competitiveness can be studied by individual’s emotional intelligence and organizational behaviour (Love, Edwards, and Wood, 2011).

According to ISO 31000:2009, risk management “*refers to a coordinate set of activities and methods that is used to direct an organization and to control the many risks that can affect its ability to achieve objectives*”. When concerning any sector, industry, services, project or activity, it requires the use of models or theories as guidelines. Therefore when its basic elements comprehend human behaviour and/or uncertainty, risk management in order 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 particular challenges when approaching specific needs, such as the mining sector. The ILO convention (C175, 1995) 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 in the preparation and implementation of safety and health measures concerning the hazards and risks they face in the mining industry*”, and furthermore recognizes “*that it is desirable to prevent any fatalities, injuries or ill health affecting workers or members of the public, or damage to the environment arising from mining operations*”. In this context, risk assessment of integrated operations can be improved by complex risk models and dynamic environments (Grøtan, Størseth and Albrechtsen, 2011).

Hence, complex systems can provide decision makers a supporting tool comprising a three axis analysis model. Each of the three axis (X, Y and Z) comprehends a multi-variable linear function  $f_i$ : X:  $f_1$  (management variables related to mining); Y:  $f_2$  (variables related to risk management systems) and Z:  $f_3$  (variables related to complex systems). Such a proposal, designing, developing and testing a risk management decision making model within complex systems, transversal to other hazard sectors of all economic activities, may provide organizations with sustainable and integrated risk management indicators.

Key Words: complex systems; risk management, uncertainty, human behaviour, high hazards

### 1. INTRODUCTION

Currently risk management is an important tool for any business sector. In an economy of global scale and high volatility due to uncertainty of the markets, this tool is even more important because through it can obtain high productivity gains.

In some industries risk management has to be taken particularly seriously because of the potential of project failure on public safety or the environment, e.g. in the mining sector due to risk perception, feasibility decision making and uncertainty.

Technical and socioeconomic complexity and organizational culture are amid the main characteristics of complex systems.

In the same sense the mining sector is by nature complex, comprehending namely, major hazards, socioeconomic impacts and resource nationalism.

The innovative aspect of this paper is that it intends to present the above mentioned variables in a multi-variable linear function analysis methodology approach thru complex system modelling and effectively correspond to a risk management tool in the mining sector.

## 2. COMPLEX SYSTEMS

In physical sciences when joining or connecting a large number of 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. Complexity as in collaborative design, comprehends the interaction of many participants, working on different elements of the design (Klein et al., 2003), such as in diverse economic activity sectors (e.g.: mining sector).

### 2.1 Complex thought

The complex thought is an instrument of change and resilience and is a method in the sense of Descartes and its main objectives are embodied in Table 1 (Mariotti, 2010).

Table 1: Objectives of Complex Thought

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

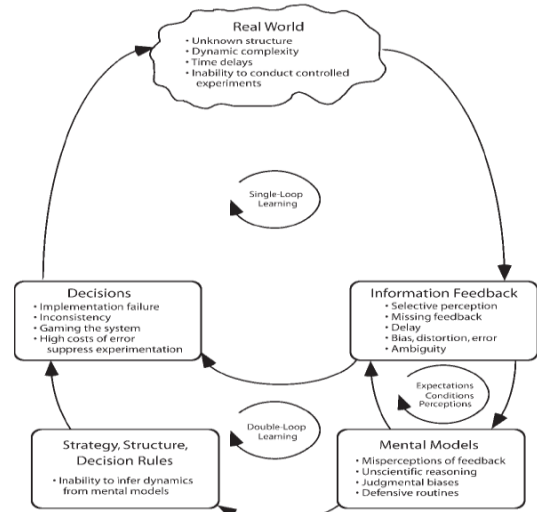
Contrasting a dynamic, ever-changing and multiway world, human mental models support decisions, making processes normally tied, conservative and narrow-minded and “*like organisms, social systems contain intricate networks of feedback processes, both self-reinforcing (positive) and self-correcting (negative) loops*” (Stermann, 2006).

### 2.2 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 (USA) “systemic” designation, thru the Morin (2006) “complex” classification, to the need of a unified terminology claimed by Mariotti (2000), complexity overlaps multiple labels and approaches. According to Morin (2006) complexity must be perceived as a “fabric” (what is woven together) of heterogeneous inseparable associated constituents (...) when trying to understand complex and complexity.

In general complexity is defined in terms of potential states in a system or the number of components (Stermann, 2006) and what is particularly important to identify, is the origin of complexity, its level and its implications (Ameen and Jacob, 2009).

Human behaviour and uncertainty are the touchstone to complexity’s basic research as established by many authors.



Note. The diagram shows the main impediments to learning. Arrows indicate causation.

Figure 1: Feed-back process of learning (Stermann, 2006)

### 2.3 Complex systems and complex projects

A complex system implies software, cultural and political issues and obviously people and organisations that can be able to affect whole or a part of a system (Marashi and Davis, 2006). How much more complex a system, more controlled must be the local environment (Sayama, 2003) and also knowing the nature and the many expression ways of complex systems in organizations can be an important tool for the managers (Amaral and Uzzi, 2007).

Each different context: simple, complicated, complex, chaotic; requires different managerial responses (Snowden and Boone, 2007). In this sense, the world of systemic thinker “soft” is complex, chaotic and ever-changing, but also accept as true that based on a process of questioning can be a suitable learning system (Checkland, 2011).

Organizational behaviour and individual’s emotional intelligence may support studies concerning the complex interconnection between individuals in an organization or a project team and its impact on competitiveness (Love, Edwards, and Wood, 2011). The cognitive systems engineering maintains that the cognitive system is capable of controlling their behaviour using information about itself and the situation, where information can be prior (competence, knowledge) to a specific situation (feed-back, indicators) and constructs (hypotheses, assumptions) (Hollnagel, 1998).

The discussion of the complexity behaviour of a system at different scales does not explain why the

systems should be simple or complex but a “profile” that quantifies the relationship between independence, interdependence and scale of collective behaviour may give help to this response (Bar-Yam, 1997). When a complex system adapts to disruptions and changing conditions that is what they call resilience also understood as an emergent property of the complex system (Dahlberg, 2015).

Resilience engineering (for safety management) exists to help people to deal with complexity under pressure to achieve success (Hollnagel, Woods, and Leveson, 2006). To understand the complex systems approach in the design and implementation phases must recognize the many differences between the traditional practices of engineering and the natural evolutionary process (Bar-Yam and Kuras, 2003). The response of hierarchical control structures, control and central planning are limited and inadequate as a solution to social complex problems and the social functioning of complex organizations (Bar-Yam, 2003).

A systemic methodology based on negotiation and argumentation to help in the resolution of complex issues and to facilitate evaluation options during design of such systems is proposed by Marashi and Davis (2006) and the decision-making processes when supported in the quantification of complex areas leave reinforced because they help set priorities and direct management efforts (Sivadasan, et al, 2010).

To deal with ambiguity and interdependency, people seek a sense of resolve plausibly and move on, that they call moments of sense making (Weick, Sutcliffe and Obstfeld, 2005). The multiple perspectives of complex situations are supported in terms of decision by the combination of two methods: “Multiple criteria decision making” and “techniques from soft systems” (Petkov, et al, 2007).

It was proved that the complexity of the projects is imperative to establish exceptional preventive measures (Domingues, 2012). In order to obtain a measure of the project complexity, Fitsilis and Damasiotis (2015) study the variables, time, cost and quality, and the three in combination, which proved that the project complexity can have a logical and valid representation.

On the other hand, others researchers present a framework for project complexity that identifies both technical and organizational complexity. For Bosch-Rekvelde et al. (2011), the majority of the elements in the technical category of the framework have a structural character, like the number of goals, largeness of scope, number of tasks, dependencies between tasks, etc., and uncertainties in goals and methods are covered in the elements from the technical category. Further, the stakeholder’s

multiplicity and multi-objectivity are covered in elements like goal alignment (technical category), the number of stakeholders and the variety of stakeholder’s perspectives (environmental category) (Bosch-Rekvelde et al., 2011)

### 3. COMPLEX RISK MANAGEMENT

Complexity offers an interesting theoretical framework to the obligatory interdisciplinary studies of integrated safety management and risk management methods (Le Coze, 2005). A risk management strategy must be developed in order to identify as many potential risks as possible and then to decide how to deal with them. Risk analysis is an important process of risk management that can identify and evaluate risk which has to be controlled, minimized or accepted, essential information for the identification of threats and vital elements for decision making (Bosch-Rekvelde et al., 2011).

The focus of engineering is on the risk factors, the development and implementation of the measures of control, from design; construction; operation processes; systems maintenance and operation limit states; such as emergencies, starting and stop processes (Domingues et al., 2013).

The traditional risk analysis is not sufficient to recognize the heterogeneity of the input criteria (*wildness in wait*) because it does not recognize the difference between the assumptions aimed at emerging order nor the possibility of heterogeneity of criteria to be incorporated in such apparent order. “Hence, (...) Risk Assessment (as part of Governance) should be recognized as a (social) knowledge practice (...)”, (Grøtan, Størseth and Albrechtsen, 2011).

Perminova et al. (2008) explained the link between uncertainties and risk management and introduced a new perspective on uncertainties in projects and how to manage them. Traditional risk management assume risk as uncertainty, the author understands risk as one of the implications of uncertainty. They define uncertainty as “a context for risks as events having a negative impact on the project’s outcomes, or opportunities as events that have beneficial impact on project performance” (Perminova et al., 2008).

Risk management needs to be thoroughly defined; such is the case in ISO 31000:2009 “refers to a coordinate set of activities and methods that is used to direct an organization and to control the many risks that can affect its ability to achieve objectives”. In a similar context, an important change related to risk perception can be found in ISO 9001:2015. Risk management integration approach, more than the traditional view as an aspect of quality,

is now a major component of the organisational culture.

According Afgan, and Veziroglu (2012) the change of social elements (health hazards) is a property of complex systems, some of these social changes are an inherent characteristic of a system: mutual interaction between the system and its surrounding are imminent and the changes in their interaction rate will affect it safety. If these processes are in steady state, it can be considered that the system is safe and because that it is of interest to investigate the essential characteristics of construction sites (or other hazardous sectors e.g.: mining sector) system which may lead to the resilience change.

In prevention domain, the most effective elements of a safety program are: the support of top management commitment, the selection of human resources (own or outsourced) and strategic management, in turn, the least effective factors are the records, accident analysis and planning of emergency (Hallowell and Gambatese, 2009). It has also been discussed, the specifications that oil refining industry brings to the role of safety technicians and the need of training about the impact of maintenance activities in the industrial process (Cardoso et al., 2014).

In order to demonstrate how the risk can be managed in high risk workplaces, one way might be through the analysis of communication gaps (Rasmussen and Lundell, 2012). Jaafari (2001) states that risk management should have a strategy-based project management approach, using life cycle objective functions, as the main drivers for risk reduction and value addition. Systematic management of complex projects needs important information skills and decision support systems which can combine the management of “hard” and “soft” aspects, and facilitate decision evaluation on a real time basis (Jaafari, 2001).

#### 4. DISCUSSION

Risk management's guidelines need the support of models and/or theories in every sector, industry, services, organization or project. Thus, to achieve effectiveness and adaption to reality as much as possible, risk management as a consequence of its basic elements, human behaviour and/or uncertainty, must be operational within complex systems, as already inferred in different R&D environments

Risk management faces particular challenges when approaching specific needs, such as the mining sector: *“that workers have a need for, and a right to, information, training and genuine consultation on and participation in the preparation and*

*implementation of safety and health measures concerning the hazards and risks they face in the mining industry”*, established by ILO convention C175 (1995) concerning Safety and Health in Mines. The same ILO regulation furthermore recognizes *“that it is desirable to prevent any fatalities, injuries or ill health affecting workers or members of the public, or damage to the environment arising from mining operations”*. In such sense, risk assessment of integrated operations can be enhanced by complex risk models and dynamic environments (Grøtan, Størseth and Albrechtsen, 2011).

The mining sector faces unprecedented challenges due to unexpected internal factors (lack of trained people or frequent equipment failures) and external factors (mineral commodity prices, market volatility, increasing regulations, dwindling profits and changing global demand) and an inadequate risk management can lead to failure in production and sometimes serious injuries in people and environment, those events can interrupt projects and even the complete loss of the business (Kumar, 2015). Badri (2015) *“puts into perspective the complexity of the challenge of integrating OHS into industrial project risk management”* and the interdisciplinary of this problem must be the starting point of any research (Badri, 2015).

Mining industry is complex due to the numerous and different operations, so that, its principal concern is safety. To Haas and Yorio (2016) the performance of an health and safety management systems (HSMS) is *“a critical and pressing issue for organizations”*, their study analyses the state of the methods on HSMS, recommending reports based on three metric categories: organizational performance, worker performance and interventions. Nelitz, at al. (2015) consider that the principal environmental stressors in this field are: human intrusion in ecosystems, gas emissions, noise and dust in the air, soil disturbance and contamination, linear infrastructure, traffic and solid waste in land, water pollution. These vectors must be considered for any risk management analysis in mining industry.

#### 5. CONCLUSIONS

Decision makers find in complex systems a supporting tool. Such an algorithm proposal is designed based upon a three axes (  $X$  ,  $Y$  ,  $Z$  ) analysis model. Each of the three axes comprehends a multi-variable linear function  $f_i$ :

$X$  :  $f_1$  (mining management variables);

$Y$  :  $f_2$  (risk management systems variables);

$Z : f_3$  (complex systems variables).

A risk management decision making model, designed, developed and tested within complex systems, aimed at being transversal to other hazard sectors in any economic activity, may provide sustainable and integrated risk management indicators to organizations.

Table 2: Variables proposal

| VECTOR ANALYSIS         |                              |                      |                                          |                                                        |                                  |
|-------------------------|------------------------------|----------------------|------------------------------------------|--------------------------------------------------------|----------------------------------|
| X                       |                              | Y                    |                                          | Z                                                      |                                  |
| M                       | Mining                       | R<br>M<br>S          | Risk<br>Management<br>Systems            | C<br>S                                                 | Complex<br>Systems               |
| $f_1$                   | related to<br>mining         | $f_2$                | related to risk<br>management<br>systems | $f_3$                                                  | related to<br>complex<br>systems |
| $x_1$                   | major<br>hazard<br>industry  | $y_1$                | Risk<br>perception                       | $z_1$                                                  | technical<br>complexity          |
| $x_2$                   | Resource<br>nationalism      | $y_2$                | feasibility<br>decision<br>making        | $z_2$                                                  | Organization<br>culture          |
| $x_3$                   | socio<br>economic<br>impacts | $y_3$                | uncertainty                              | $z_3$                                                  | socio<br>economic<br>complexity  |
| $x_n$                   |                              | $y_n$                |                                          | $z_n$                                                  |                                  |
| PLAN ANALYSIS           |                              |                      |                                          |                                                        |                                  |
| $XY : (f_1, f_2)$       |                              | M vs RMS             |                                          | e.g.: (Haas and Yorio, 2016)                           |                                  |
| $XZ : (f_1, f_3)$       |                              | M vs CS              |                                          | e.g.: (Nelitz, at al., 2015)                           |                                  |
| $YZ : (f_1, f_3)$       |                              | RMS vs CS            |                                          | e.g.: (Badri, 2015)                                    |                                  |
| VOLUME ANALYSIS         |                              |                      |                                          |                                                        |                                  |
| $XYZ : (f_1, f_2, f_3)$ |                              | M vs<br>RMS vs<br>CS |                                          | Risk Management<br>Within Complex<br>Systems in Mining |                                  |

This analysis methodology above proposed, is supported by a three-dimensional scope,  $F = (f_1, f_2, f_3)$  (complex systems, risk management, mining sector), being  $F$  a comprehensive model of analysis that can be used to determine scenarios among different options, where several objectives can be set: “zero accidents”. Mining sector can thus be thought as a complex system and risk understood as a management variable and integrated through the risk management function.

## 6. REFERENCES

- Afgan, N. and Veziroglu, A. (2012). Sustainable resilience of hydrogen energy system. *International Journal of Hydrogen Energy*, 37, 5461-5467.
- Amaral, L. A. N. and Uzzi B. (2007). Complex Systems - A New Paradigm for the Integrative Study of Management, Physical, and Technological Systems. *Management Science*, 53(7), 1033-1035.
- Ameen, M. and Jacob M. (2009). Complexity in Projects: A Study of Practitioners Understanding of Complexity in Relation to Existing Theoretical Models. In *School of Business 2009*, Umeå University: Umeå, Sweden.
- Badri, A. (2015). The Challenge of Integrating OHS into Industrial Project Risk Management: Proposal of a Methodological Approach to Guide Future Research (Case of Mining Proj. in Quebec) *Minerals* 5, 314-334. doi:10.3390/min5020314.
- Bar-Yam, Y. (1997). Complexity Rising: From Human Beings to Human Civilization, a Complexity Profile, N.E.C.S. Editor, New England Complex Systems Institute: Cambridge, MA, USA.
- Bar-Yam, Y. and Kuras M. L. (2003). Complex Systems and Evolutionary Engineering, in *An AOC WS LSI Concept Paper*, Complex Systems Institute and The MITRE Corporation.
- Bar-Yam, Y. (2003). When Systems Engineering Fails - Toward Complex Systems Engineering, in *International Conference on Systems, Man & Cybernetics*, I. Press, Editor New England Complex Systems Institute: Piscataway - NJ, USA.
- Bosch-Rekveltda, M., Jongkindb, Y., Mooia, H., Bakker, H., Verbraeckb, A. (2011). Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *International J. of Project Management*, 29(6), 728-739. doi:10.1016/j.ijproman.2010.07.008.
- Cardoso, A., Queiroz, S., Fernandes, A., Roçadas, A. S. and Diogo, M. T. (2014). Técnico de Segurança numa refinaria: responder às especificações de uma indústria. *Proceedings Book of SHO 2014 – Intern. Symposium on Occupational Safety and Hygiene*, Guimarães, Portugal.
- Checkland, P. (2011). Autobiographical retrospectives: Learning your way to ‘action to improve’ – the development of soft systems thinking and soft systems methodology. *International Journal of General Systems*, 40(05), 487-512.
- Dahlberg, R. (2015). Resilience and Complexity: Conjoining the Discourses of Two Contested Concepts. *Culture Unbound*, Volume 7, 541-557. Published by Linköping University Electronic Press
- Domingues, M. S. Q. (2012). Uma abordagem aos projetos complexos na perspectiva da prevenção. *Dissertation of Master Degree in Engineering of Occupational Safety and Hygiene*, University of Porto, Portugal, 92 p.

- Domingues, M. S. Q., Roçadas, A. S. A., Fernandes, A. F., Silva, C. O., Martins, J. M. M., Cabral, A. M. and Diogo, M. T. (2013). Complex Systems Application at Risk Prevention in Processing and Use of Hydrogen Technologies. In IV Iberian Symposium on Hydrogen, Fuel Cells and Advanced Batteries, Estoril, Portugal.
- Fitsilis, P. and Damasiotis V. (2015). Software Project's Complexity Measurement: A Case Study. *Journal of Software Engineering and Applications*, 8, 549-556.
- Grøtan, T. O., Størseth, F., and Albrechtsen, E. (2011). Scientific foundations of addressing risk in complex and dynamic environments. *Reliability Engineering and System Safety*, 96(6), 706-712. doi: 10.1016/j.ress.2010.12.009.
- Haas, E. J. and Yorio, P. (2016). Exploring the state of health and safety management system performance measurement in mining organizations. *Safety Science* 83 (2016) 48–58.
- Hallowell, M. R. and Gambatese, J. A. (2009). Construction Safety Risk Mitigation. *Journal of Construction Eng. and Management*, 135(12), 1316-1323. doi: 10.1061//asce/co.1943-7862.0000107.
- Hollnagel, E. (1998). Commentary Comments on "Conception of the cognitive engineering design problem" by John Dowell and John Long. *Ergonomics*, 41(2), 160-162.
- Hollnagel, E., Woods D. D., and Leveson N. G. (2006). *Resilience Engineering Concepts and Precepts*. Aldershot, Hampshire, England: Ashgate Publishing Limited. 410.
- International Labour Organization (1995). *Convention N. 176 - Safety and Health in Mines Convention*.
- Jaafari, A. (2001). Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management*, 19(2), 89-101. doi:10.1016/S0263-7863(99)00047-2.
- Klein, M., Faratin, P., Sayama, H., and Bar-Yam, Y. (2003). The Dynamics of Collaborative Design: Insights from Complex Systems and Negotiation Research. *Concurrent Engineering*, 11(3), 201-209. doi: 10.1177/106329303038029.
- Kumar, P., Rathore, I. (2015). The Need of Mining Industry – A SWOT analysis. *International Research Journal of Earth Sciences*, 3(8), 32-36.
- Le Coze, J. (2005). Are organisations too complex to be integrated in technical risk assessment and current safety auditing? *Safety Sc.*, 43, 613–638.
- Love, P., Edwards, D., and Wood, E. (2011). Loosening the Gordian knot: the role of emotional intelligence in construction. *Engineering, Construction and Architectural Management*, 18(1), 50-65. doi: 10.1108/09699981111098685.
- Marashi, E. and Davis, J. P. (2006). An argumentation-based method for managing complex issues in design of infrastructural systems. *Reliability Engineering & System Safety*, 91(12), 1535-1545.
- Mariotti, H. (2000). Reduccionismo, "Holismo" e Pensamentos Sistêmico e Complexo (Suas consequências na vida cotidiana). In P. Athena (Ed.), *As paixões do ego: complexidade, política e solidariedade*. São Paulo, Brasil.
- Morin, E. (2006). *Introdução ao Pensamento Complexo*. Edit. Sulina, ISBN: 978-85-205-0598-4.
- Nelitz, M. A., Beardmore, B., Machtans, C. S., Hall, W. A., and Wedeles, C. (2015). Addressing complexity and uncertainty: conceptual models and expert judgments applied to migratory birds in the oil sands of Canada. *Ecology and Society* 20(4):4. doi:10.5751/ES-07906-200404
- Perminova, O., Gustafsson, M., Wikstro, K. (2008). Defining uncertainty in projects – a new perspective. *International J. of Project Management*, 26(1), 73-79. doi:10.1016/j.ijproman.2007.08.005
- Petkov, D., Petkova, O., Andrew T., Nepal T. (2007). Mixing Multiple Criteria Decision Making with soft systems thinking techniques for decision support in complex situations. *Decision Support Systems*, 43, 1615–1629.
- Rasmussen, J. and Lundell, Å. K. (2012). Understanding "communication gaps" among personnel in high-risk workplaces from a dialogical perspective. *Safety Science*, 50(1), 39-47. doi: 10.1016/j.ssci.2011.06.009
- Sayama, H. (2003). *Workplace Construction: A Theoretical Model of Robust Self-Replication in Kinematic Universe*. In Eighth International Symposium on Artificial Life and Robotics.
- Sivadasan, S., Smart, J., Huatuco, L. H., et al., (2010). Operational complexity and supplier–customer integration: case study insights and complexity rebound. *Journal of the Operational Research Society*, 61(12), 1709-1718.
- Snowden, D. J. and Boone M. E. (2007). *A Leader's Framework for Decision Making*. Harvard Business Review.
- Sterman, J. D. (2006). Learning from Evidence in a Complex World. *American Journal of Public Health*, 96(3), 505-514.
- Weick, K. E., Sutcliffe K.M. and Obstfeld D. (2005). Organizing and the Process of Sensemaking. *Organization Science*, 2005. 16(4), 409-421.