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A CIA–ISM scenario approach for analyzing complex cascading effects in Operational Risk Management

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ABSTRACT

This is the first paper to apply a combination of HAZOP and Risk Consequence Matrix plus Cross Impact Analysis (CIA) and Interpretative Structural Modeling (ISM) methods for analyzing complex cascading effects in Operational Risk Management in an industrial environment. This combination of methods allow obtain more information than using HAZOP and Risk Consequence Matrix because upgrades the individual risk analysis with the correlation between risks. Its main objective is to improve the understanding of the overall picture of an organization's risks. The paper summarizes the development of the combination of this methods of the interaction of 18 critical events of an industrial plant as a first step to improving organizational resilience based on the company's own estimations as well as the estimates of an expert panel. The main benefit of using these methods is to know the relationships between different risks and consequences, direct links, indirect and cascading effects. Having the possibility of knowing a full risk map and being able to make a forecast will help to mitigate the unexpected/unprepared effects and have a better response making better decisions after an emergency situations is the same as being more resilient.

1. Introduction

For any organization to have the ability to prevent, adapt, mitigate and recover from unintended, unexpected and negative effects for the Organization (Vogus and Sutcliffe, 2007; Mileti, 1999; Labaka, 2013; Labaka et al., 2012, 2013) can mean the difference between surviving or not. In particular, for large industrial organizations with higher risk levels where the potential economic and human losses are very high (Oliver-Smith, 2002), having these skills is absolutely necessary. To have these characteristics is to be resilient and this concept is linked to the literature on the management of accidents, emergencies, business continuity and disaster recovery. This article is a study of a real case in which a risks and consequences scenario is created in an industrial plant using previous risk analysis documentation (Hazop and Risk Consequence Matrix) plus Cross Impact Analysis (CIA) and Interpretive Structural Modeling (ISM) (Fig. 1). At the end, the application of this methodology is highlighted as it improves the prior knowledge of the Organization in terms of its risk map, thus offering the possibility of generating predictions that help the Organization to be more resilient and to expect the unexpected.

Scenario methods should be capable of handling large amounts of information and quantitative and qualitative data. For example, a study that includes 18 events, such as the one described below, should consider 1.7403456$e+16$ possible outcomes [$P(n)=e*N!$] (Turoff, 1972), making it almost impossible to evaluate all the different paths using the currently applied methods in Operational Risk Management. The CIA–ISM method (Bañuls and Turoff, 2011) overcomes this limitation due to its computational capabilities. CIA–ISM has been successfully applied in emergency situations analysis and has had very good results (Bañuls et al., 2013; Lage et al., 2013). In this paper we go a step further by applying this methodology in a new area: industrial risk analysis. This scenario methodology allows us to represent the concatenation of events that have a very low probability of occurrence but can be disastrous in the case of several occurring simultaneously in industrial contexts. The history of calamities such as the BP disaster, Bhopal, and the Chernobyl nuclear accident point to the potential value of using multiple scenarios – not to select the most likely one, but to train users in becoming familiar with a wide variety of shocks

Abbreviations: AHI, Accident Hazard Analysis; ASP, Accident Sequences Precursor; CIA, cross-impact analysis; CIASS, web-based tool for simulation and forecasting. www.ciass.org; ETA, Event Tree Analysis; FEI, Dow Fire and Explosion Index; FMEA, Failure Mode Effect Analysis; FMECA, Failure Mode Effect Criticality Analysis; HAZOP, Hazard and Operability; HRO, High Reliability Organization; HRT, High Reliability Theory; ISM, Interpretative Structural Modeling; MCAA, Maximum Credible Accident Analysis; NAT, Natural Accident Theory; PSA, Probabilistic Safety Analysis; RBD, Reliability Block Diagram

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and unanticipated situations, be they hostile or not, thereby becoming superior crisis managers when confronted with a novel emergency (Bañuls et al., 2013).

This first section describes a short literature review and methodology background following the case study where the organization, the events and all the processes to elaborate a CIA–ISM are described. Next, the results are presented, including the Matrix and Chart for CIA–ISM and the scenarios forecasted. At the end, we explain how the CIA–ISM method could be used as a part of a decision support system, helping us to deal with non-obvious results. Finally the conclusions, limitations and future research lines are defined.

2. Literature review

The Normal Accident Theory (NAT) (Perrow, 1984), the High Reliability Theory (HRT) (Roberts, 1990; La Porte, 1996; Van den Eede, 2009), or approaches such as Petroski's (1994) and Dörner's (1989) try to show the best way to deal with situations of risk, crisis, disaster, and unwanted events. They all emphasize that the two main issues to address are the complexity of each case and evaluating the uncertainty associated directly with the concept of risk and the environment. The paradox that occurs when NAT and HRT are compared can also be seen, showing that they can be taken as complementary and not antagonistic theories to expect the unexpected (another definition of resilience) (Weick and Sutcliffe, 2007a). These same authors have an extensive work about High Reliability Organizations (HRO), explaining the reasons about why they have fewer accidents than would be expected (Weick and Sutcliffe, 2007b). Preoccupation with failure, sensitivity to operations, reluctance to simplify interpretations, deference to expertise and commitment to resilience are five common HRO processes. The methodology applied in this article (CIA–ISM) is adverse to simplification, takes data from experts' opinions, and can be a great tool to increase the organizational resilience level if the organization wants to deal with risk and crisis situations and minimize their occurrence.

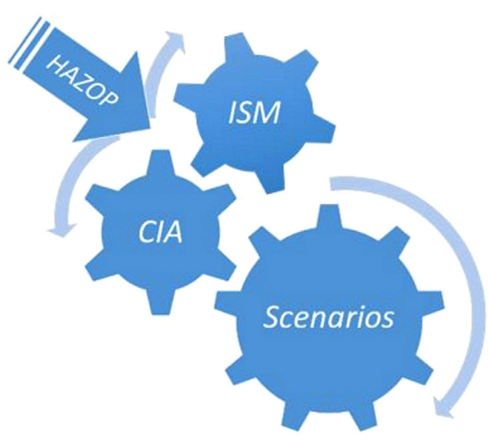

Fig. 1. Methodology process.

Improved levels of resilience are almost mandatory for industrial organizations but there are problems due to the uncertainty and complexity of each case. It is therefore necessary to have a tool capable of working with risks, and complex and dynamic environments. Reviewing the literature, we found that the generation of scenarios has been used to improve the capacity to respond to disasters and threats (Eriksen, 1975), prediction and estimates on earthquake disasters (Fedotov et al., 1993; Barbat, 1996; Kappos et al., 1998), as well as resource planning and strategies (Ringland, 1998; Nguyen and Dunn, 2009) and, finally, for emergency planning (UNDHA, 1993; Alexander, 2000; Bañuls et al., 2010, 2013; Aedo et al., 2011; Turoff et al., 2013a, 2013b, 2014) where techniques have been applied to generate scenarios to address and predict crises, disasters, to ameliorate the management of such situations, to better responses and to train emergency teams.

Tixier et al.'s work about risk analysis methodologies of industrial plant must be considered. This is a review of 62 methodologies (Tixier et al., 2002), categorizing them according to 4 properties (deterministic, probabilistic, qualitative and quantitative). The authors explain that the different methods can be categorized using the kind of input data (plans or diagrams, Process and reactions, Substances, probability and frequency, policy and management, environment, and text and historical knowledge). It also should be noted that most of the methods concerning risk analysis only consider each risk individually. Table 1 shows some examples described in the Tixier et al.'s paper.

Reading Tixier et al.'s paper is highly recommendable to see a complete description of this classification. In this way, HAZOP and the Risk Consequence Matrix plus the CIA–ISM methods used in this paper could be categorized as a Mix method that joins together the 4 properties and both kinds of output data. CIA–ISM can generate scenarios, categorize the events, observe relationships and generate predictions. This is very interesting for the Organization because it can work with all kinds of qualitative and quantitative data, using not only pre-existing security and prevention plans data but also being enriched by the experts' point of view, using the Delphi method or a survey of them. In the next section we introduce the fundamentals of this methodology.

3. CIA–ISM fundamentals

CIA–ISM (Bañuls and Turoff, 2011) combines Cross Impact Analysis (CIA) and Interpretive Structural Modeling (ISM) with good results in the management of emergencies, being able to identify the most important risks, the relations between them, direct effects, indirect effects and cascading effects and predict the most important elements. Other applications of this method can

Table 1
Risk analysis categorization with examples. .
(*Source*: Tixier et al. (2002)).

	Qualitative	Quantitative
Deterministic	• Failure Effect Analysis (FMEA) • Hazard and Operability (HAZOP)	• Accident Hazard Analysis (AHI) • Dow Fire and Explosion Index (FEI)
Probabilistic	• Accident Sequences Precursor (ASP) • Delphi Technique	• Delphi Method • Event Tree Analysis (ETA)
Deterministic And Probabilistic	• Maximum Credible Accident Analysis (MCAA) • Reliability Block Diagram (RBD)	• Failure Mode Effect Criticality Analysis (FMECA) • Probabilistic Safety Analysis (PSA)

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