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A hybrid model for learning from failures: The Hurricane Katrina disaster

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ABSTRACT

There is a need to facilitate learning from failures in the context of natural and man-made disasters. This paper investigates the multi-faceted nature of research in disasters and the aspect of hybrid approaches in modelling within this domain. The paper applies a framework of reliability and multiple criteria decision analysis techniques to the case of the Hurricane Katrina disaster of 2005. It is shown how this hybrid model can be used through an integrative approach to perform a systematic analysis that can lead to learning from failures.

The proposed framework incorporates and integrates Fault Tree Analysis (FTA), Reliability Block Diagram (RBD) analysis and the Risk Priority Number (RPN) concept, together with the Analytic Hierarchy Process (AHP) which is used as a simulation model for decision support. It is shown how the proposed integrated framework can contribute to our understanding of failures and enhances the ability to extract lessons from failures or disasters. Such lessons are then mapped into specific decisions for prevention, and resource allocations, to help avoid a repeat disaster.

1. Introduction[1]

Previous research has shown that organizations learn more effectively from failures than from successes (Madsen & Desai, 2010) and that failures contain valuable information, but organizations vary in their ability to learn from them (Desai, 2008). It has also been argued that there is a need for a paradigm shift in accidents models due to new challenges that relate to issues such as the fast pace of technological change, the changing nature of accidents, decreasing tolerance to single accidents and increasing complexity and coupling (Leveson, 2004). Pavlou and El Sawy (2011) investigated means of measuring dynamic capabilities and concluded that among its properties are learning, sensing the environment, coordinating and integrating. Also, learning can be enhanced through developing simulations and mental models (Clark & Kent, 2013).

Research into disasters and learning from them is multi-faceted in nature (Kulatunga, 2010). Labib and Read (2013) investigated the issue of learning from failures and applied reliability analysis techniques of Fault Tree Analysis (FTA) and Reliability Block Diagrams (RBD) as a framework model for learning from failures. This was based on the analysis of four case studies related to reported disasters, which included the Titanic disaster, the BP Texas City incident, the Chernobyl disaster, and NASA's Space Shuttle Columbia accident. Reliability engineering techniques such as FTA, RBD and Failure Mode, Effects and Criticality Analysis (FMECA) have been used to analyse the case of the Bhopal disaster (Labib & Champaneri, 2012), and it has been shown how such techniques can help in building a mental model of describing the causal effects of the disaster. The same case study of Bhopal was also investigated (Ishizaka & Labib, 2013) and a new logic gate in a fault tree was proposed for analysing disasters and the benefits of using hybrid techniques of multiple criteria and fault analysis to evaluate and prevent disasters were demonstrated. Hybrid modelling has recently been adopted by several authors. For example, Kou, Ergu, and Shi (2014) provided an efficient hybrid model that integrates fuzzy logic, survey questionnaires, Delphi and multiple criteria decision making (MCDM) methods for disaster assessment. Li, Li, Liu, Khan, and Ghani (2014a) provided a community-based virtual database for emergency management. Also Li, Tang, Sun, and Wu (2014b) developed a mult-objective optimisation model for oil-importing decisions in extreme events. Zolfani, Esfahani, Bitarafan, Zavadskas, and Arefi (2013) proposed a hybrid MCDM method for the selection of a tunnel ventilation system in the event of automobile accidents. Vaidogas and Šakėnaitė (2010) proposed a hybrid model for fire risk in the form of quantitative risk

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[1] This research builds on and extends previous work in chapter 10 of Labib (2014).

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assessment and multi-attribute selection. Poplawska, Labib, and Reed (in press) proposed a hybrid multi criteria decision analysis framework for implementation of corporate social responsibility (CSR) in the extractive sector.

Tinsley, Robin, and Matthew (2012), who investigated near-miss events as well as Hurricane Katrina and other disasters, concluded that "*people may be complacent because prior experience with a hazard can subconsciously bias their mental representation of the hazard in a way that often (but not always) promotes unrealistic reassurance*". This paper extends this work on Hurricane Katrina disaster, by providing and integrating tools that can help in performing a systematic analysis that can lead to learning from failures. It is hoped that this hybrid modelling approach will contribute to the provision of a useful mental representation of disasters.

In this paper, a number of reliability analysis techniques are employed. FTA is used to identify the main direct causes and contributing factors (failure modes) of the Hurricane Katrina disaster, and to show how these direct causes and contributing factors interacted with each other. The interactions identified through FTA are used as an input to an RBD analysis, to demonstrate how overall system reliability could be calculated and improved through, for example, strengthening weak (series) structures revealed by the analysis. The failure modes identified through the FTA analysis are used as input for an FMECA analysis for the identification of a Risk Priority Number (RPN) of each failure mode which can be used to rank the risk of different failure modes.

Leveson (2004) argued that event based accident models, such as FTA, RBD and FMECA, have limitations due to their emphasis on linear causality and inability to deal with non-linear relationships such as feedback, and may give only a superficial explanation about why a disaster may have occurred. In order to overcome this limitation and contribute to the provision of a deeper understanding of the reasons for failure as well as support for decision making, this present paper employs multi-criteria decision making (MCDM) techniques to structure and analyse the information provided by the reliability techniques. The work presented here utilises the MCDM technique of Analytic Hierarchy Process (AHP) to provide prioritisation, sensitivity analysis and feedback on consistency of the different criteria and the alternative contributing factors. The model helps the decision maker to prioritise different strategies and the allocation of resources. It also provides a sensitivity analysis and a measure of consistency as a form of feedback. Also in this paper we discuss the high level design improvements, and the lessons learned which should be acted upon so as to avoid a repeat disaster.

Fig. 1 outlines a flowchart of the structure and relationship between the different techniques used. The three techniques of FMECA, FTA, and RBD belong to the reliability analysis domain, whereas AHP is an MCDM technique.

The contributions of the study are both theoretical and methodological. On the theoretical side, it is shown how data – some of which is based on interpretation and judgement and some is more empirical in nature – can be combined in a rich framework that can be used by decision makers to prioritise different strategies and allocation of resources. Although the chosen methods are all normative decision making or assessment techniques, and not inference techniques, by combining them one can illicit useful recommendations for policy making. On the methodological side, it is shown how the two fields of risk analysis and decision science can be combined and utilised in an integrated manner. It also shows that techniques intended for prospective decision making can be utilised to retrospective events. Finally, our use of hybrid modelling makes a contribution towards demonstration of both the 'interactive and integrative' capabilities of the chosen models.

According to Cacciabue and Vella (2010) retrospective analysis aims at understanding and extracting lessons from past events through techniques related to data mining and root cause analysis, whereas prospective analysis looks ahead and speculates safety levels of systems through brainstorming initiating events and generation of counter safety measures. They also argue that to ensure consistency and consolidation of the whole safety approach, there is a need to utilise same reference models. Hence, in this paper, the same data, methods and techniques are used for retrospective and prospective analysis.

It may be argued that single techniques have limited capacities to represent complex realities, but simply adding more techniques does not necessarily improve learning. It may make inferences harder to make, and it may introduce contradictions. We demonstrate through the narrative of the case study that the proposed hybrid integrated approach provides better understanding of the causal factors as well as provision of decision support for resource allocation and prevention of similar devastating consequences from disastrous events.

2. Analysing disasters

A disaster may be considered as a Black Swan, a term coined by Taleb (2010) to describe an event which has the three attributes of

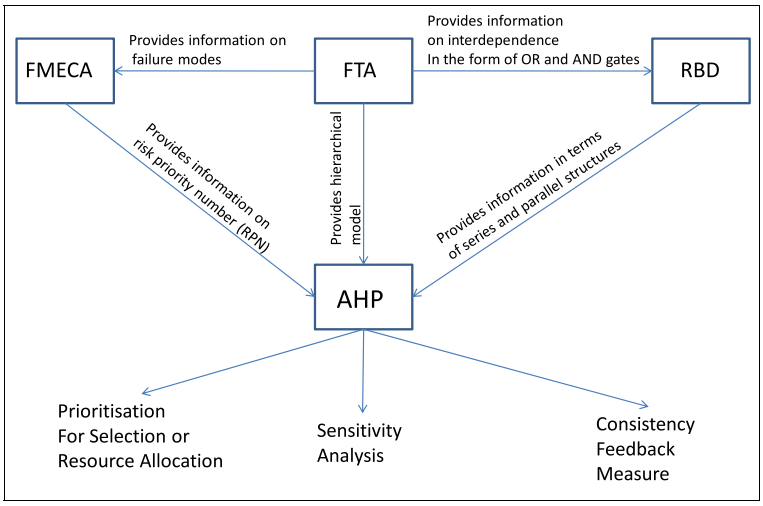

Fig. 1. The model structure and the relationships between the different techniques.