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A hybrid model for learning from failures

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ABSTRACT

In this paper we propose the usage of a hybrid of techniques as complementary tools in decision analysis for learning from failures and the reason behind systems failure. We demonstrate the applicability of these tools through an aviation case study, where an accident investigation report was obtained from the Directorate of Accident Investigation in the Ministry of Transport and Communications in Botswana to provide as a basis for the application of the model. The report included all the factual information required to carry out the investigation using the hybrid of FTA, RBD, AHP, HoQ and the DMG tools.

We discuss the steps followed in applying the tools in the process of learning from failure. It also shows the importance of such tools in accident investigations by showing the importance of prioritising the available options in order of their importance to the accident under investigation.

Most of the available research in learning from failure focuses mostly on the direct causal factors of the failure event. Here we provide a holistic approach to learning from failure by focusing on both direct and indirect causes of a failure event through the use of Reliability Engineering tools, Multi Criteria Decision Making tools and House of Quality.

1. Introduction

In many organisations failure is always the cause of conflicts as they have inherited a blame and lack of trust culture (Cox, Jones, & Collinson, 2006; and Jefcott, Pidgeon, Weyman, & Walls, 2006). Even though this is the case, some organisations view failure as an opportunity to obtain lessons for continual improvement hence a chance of gaining competitive advantage over their nearest rivals.

Failure can be defined in many different ways of which the use is influenced by the context it is used on. Torell and Avelar (2010) described failure in two distinct ways as the inability of a product or system to perform its required function and also as the inability of a component to perform its required function without hindering the function of the product as a whole.

The ability to learn from failures helps organizations, engineers and designers to put in place measures to avert the same inadequacies from re-occurring. Labib (2015) explains that for clear understanding of the causes of a failure, there is a major need to analyse four factors, which are; human, design, organizational and socio-cultural factors.

By doing so Labib and Read (2015) suggested that four main benefits could be obtained that include easy identification of root causes of the failure and the associated reasons. The other benefit is that such analysis of failure can help to institute long term plans to prevent similar events from re-occurring and can also act as an early warning signal just prior to the event in order for defensive actions to be taken. They also suggested that it helps decision makers with information on priorities for resource allocation for both recovery and prevention.

Labib and Read (2015) proposed categorising of causal factors as either direct cause or contributing factors when dealing with natural disasters. This approach can also be useful when dealing with failures associated with multi-disciplinary environments such as in aviation where there is an interaction of many specialties such as operations, maintenance, air traffic control, meteorology, airport services, fire fighting etc.

When dealing with failure engineers tend to tackle only the direct causes of a failure event hence putting less or almost no effort on averting indirect causes of a failure incident. As a result these indirect causes remain unsolved hence continuing hidden in the system, with a chance of causing further failure in the future.

It is the purpose of this paper to present a hybrid model for learning from failures where both the direct causes and indirect causes of failure are investigated. This model utilises the reliability engineering tools of Fault Tree Analysis (FTA), Reliability Block

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Diagrams (RBD) and Fault Modes, Effects and Criticality Analysis (FMECA); Multi-criteria Decision Analysis techniques of Analytic Hierarchical Process (AHP) and Decision Making Grid (DMG); and House of Quality (HoQ). To explain the usefulness and application of the model a case study is used.

The next section provides a detailed literature review on how different researchers use the above-mentioned technique to learn from failure. This is followed by a brief summary of the failure event that will be used as the case study for the application of the proposed model with the subsequent section focusing on the framework itself and its application on the case study. Finally section five gives the conclusion of the report underlining the weakness and the strength of the proposed approach.

2. Theoretical frameworks

There is a number of research work carried out by scholars and industry experts in order to come up with models of learning from failures. These literature works act as a starting point for further research in this important area and also as a guide for the model proposed in this paper.

Classification of hybrid models and modelling of operational research tools can be traced back to the work of Shanthikumar and Sargent (1983), who suggested that hybrid approaches can manifest itself in two ways; either through the models and their solution procedures, or through the use of the solution procedure of independent types of models. The former option they called it 'hybrid model', whereas the latter they termed it as 'hybrid modelling'. In our approach we will focus on the former option where an output of one type of modelling can be an input to the other. In terms of types and usage of operational research (OR) models, Shanthikumar and Sargent (1983) suggested that modelling is used in five ways (i) in analysis, where modelling is used to obtain an output for a given system and input, (ii) in optimization, where the model and its solution procedure are used to find the values of the decision variables to optimize an objective function, (iii) in synthesis, where a model is developed to convert a set of inputs into a set of desired outputs, (iv) in gaining insight into a system's behaviour by developing a model of it and using its solution procedure to explore its behaviour, and (v) in the comparison of alternative systems, where modelling of various alternative systems are carried out to determine the "best" one. In our work we are interested here in two types of synthesis, and gaining insight through learning lessons from failures.

Morgan, Belton, and Howick (2016) and Morgan, Howick, & Belton, 2017 developed a good review about use of hybrid OR techniques, where they concluded that mixing OR modelling methods raises many philosophical issues and that there are arguments that suggest benefits and potential problems of mixing OR methods in general. However, they argue that real-world problem situations are highly complex and multidimensional, and potentially may benefit from different paradigms to focus on different aspects of a situation. Howick, Ackermann, Walls, Quigley, and Houghton (2017) used a case study to illustrate how one can learn from mixing OR methods and specifically they focused on the value or impact of such integration of methods. However, most of the survey literature about case studies of mixing methods tend to be applied to a hybrid f two or maximum three methods, whereas in our case we develop a framework that utilises multiple methods and we highlight the benefit of using each one.

Love, Lopez, and Edwards (2013) developed a learning framework that can be used to mitigate design errors and potential failures and accidents in the construction industry. Their framework acknowledges the fundamental pathogenic influences that contribute to errors and failures. As such it suggests that a group of approaches should be implemented simultaneously at a project, organisational and people level in order to lessen errors and failures.

Failure to do this, according to Love et al (2013) would depend on time until the next major failure is experienced. They continue by explaining that reviewing past experiences is the first step in learning from failures but the much bigger step is taking action. This is because taking action involves a major change in both behaviour and culture.

When analysing the Fukushima accident, Zubair, Park, Heo, Hassan, and Aamir (2015) noticed that there exist basic precursors of nuclear accidents that are inherently difficult to quantify with vague priorities. So, to overcome these shortfalls they proposed a model, which combined the AHP and the Bayesian Belief Network (BBN). These helped them to accomplish sensitivity analysis and prior probabilities into posterior probabilities of precursors. As such they found out that design is the most important precursor though the chance of an accident is also dependent on other factors such as culture and plant specific conditions, which can affect the distribution of prior probability. For a review of AHP in terms of its methodological variation, please see Ishizaka and Labib (2011a, b).

In their research, Ishizaka and Labib (2014) studied the Bhopal disaster and proposed a model for learning from failure. In their model they demonstrated that the FTA can be improved in Crisis Tree Analysis (CTA) in order to map a crisis with the introduction of the revolving gate as opposed to the AND and OR gate that are used in an FTA. The CTA caters for amplified impact of the input event to the final event.

They also suggested that the RBD could also map crisis with hyper-blocks as the complement of the revolving gate. Their model also utilises the AHP method to measure the criticality of the basic events. Through the use of their model more realistic and sound decisions can be made unlike when using each technique in isolation.

In a bid to show that the use of FTA and RBD can systematically help in solving complex industrial failures, Yunusa-Kaltungo, Kermani, and Labib (2017) applied these techniques to investigate a chronic rotary kiln refractory brick failure in a fully integrated cement plant. They compared the efficiency of these methods to the one that was being used in the plant that is based on Root Cause Analysis (RCA). The results obtained indicated that the investigative method that was used in the plant that is based on RCA failed to prevent future occurrences. Through the usage of FTA and RBD the investigative team obtained a holistic understanding of the failure causing factors and their interrelations hence helping in avoiding repetition in the future. Both FTA and RBD have been used in a complimentary manner (Bhattacharjya & Deleris, 2012).

Labib (2015) emphasized the importance of the FTA and RBD techniques in creating a framework for learning from failures. He used these techniques to analyse the Bhopal disaster and he concluded that they could be used to serve as both knowledge retention and decision support tools. According to Labib (2015) they can provide practitioners with guidelines to follow the root cause of the problem, equips them with the tool box leading to more effective decision making practices, process safety and environment protection.

Morgan et al. (2016) presented insights on using hybrid models by mixing OR methods of system dynamics and discrete-event simulation within a real world project. They presented the model development process, the role of each modelling method and the benefits of using such hybrid models in project design. In their work, they have shown that by using hybrid models in complementary, each model add value to the other resulting in an allround solution to the problem.

On the other hand, Labib and Read (2015) proposed a hybrid model for learning from failure that utilises both the reliability en-