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RISK ASSESSMENT IN THE SUSTAINABLE ENTERPRISE THROUGH BOW-TIE METHOD

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Abstract: A bow-tie diagram combines a fault tree and an event tree to represent the risk control parameters on a common platform for mitigating an accident. Quantitative analysis of a bow-tie is still a major challenge since it follows the traditional assumptions of fault and event tree analyses. Risk analysis is a systematic approach that gathers and integrates qualitative and quantitative information of potential causes, consequences, and likelihoods of adverse events. The correct risk assessment leads towards a sustainable enterprise.

1. INTRODUCTION

The main objective of this paper is to develop a generic framework for bow-tie analysis under uncertainties in the sustainable enterprise.

Currently a common concern, both nationally and internationally, is sustainability. Problems affecting sustainability is the opposition between the needs of population growth on the one hand and the planet's resources, the continuous degradation of the environment and new technologies on the other part.

Enterprises' sustainability generates value and develops opportunities so that this concept has become the concern of all [6]. Risk is an element present in any enterprise. Its sustainability needs risk identification within all four responsibilities of the sustainability: technological, environmental, economic and social. The essence of this development model is to establish the relationship between the human activities and the natural environment, which cannot diminish the perspectives of the next generation. Managers who understand the need for a strategic approach to corporate sustainability management will perform across the "quadruple" of technological, environmental, social and financial performance to preserve value and create new business opportunities [7].

Sustainable development of the enterprise is represented by highlighting the following objectives: one economic (creating more money based on how sustainable production and consumption are), another ecological (conservation and resource management), the third, social (equity and participation of all social groups) and technological (resource that is used in each department to create added value) [5].

2. BOW-TIE METHOD

Risk analysis is a systematic approach that gathers and integrates qualitative and quantitative information of potential causes, consequences, and likelihoods of adverse events. Likelihood of an event refers to a quantitative measurement of occurrence, which is expressed either as frequency or probability of occurrence.

Fault tree analysis (FTA) and event tree analysis (ETA) are two well established techniques in performing risk analysis for a system. From a risk analysis perspective, a fault tree develops a graphical model for a particular system through exploring the logical relationship between the causes and occurrence of an undesired event, typically termed as basic events, and a top event [10]. It uses the likelihoods of basic events as input event

data and determines the likelihood of the top event. The event tree constructs a graphical model of consequences considering the undesired event as an initiating event and identifies possible outcome events at the end [8].

FTA and ETA distinctly investigate the causes and consequences of an undesired event for a system. A bow-tie diagram is a combined concept of risk analysis that integrates a fault tree and an event tree on the left and right side of the diagram to represent the risk control parameters such as causes, threats (hazards) and consequences, on a common platform for mitigating an accident. The quantitative analysis of a bow- tie diagram determines the likelihoods of the undesired event as well as the outcome events.

Cockshott (2005), Chevreau et al. (2006), Dianous and Fiévez (2006), and Duijm (2009) describe the procedure of bow-tie analysis in detail. However, they did not consider the associated uncertainties in quantitative evaluation. In the last few years, the bow-tie method has gained acceptance as a credible risk and safety management tool because of the following advantages:

• provides a graphical representation of accident scenarios,
• provides explicit linkages between the causes and the potential outcomes,
• connects possible outcome events with the undesired event and basic events,
• provides guidance throughout, stating from basic causes to the final consequences, and
• provides systematic help in performing comprehensive risk analysis and safety assessment [2], [1], [3], [4].

The common objective of any safety assessment and risk analysis technique is to assure that a process or a system is designed and operated to meet “accepted risk” or a “threshold” criterion [4]. These techniques follow several systematic steps: hazard analysis, consequence analysis, likelihood assessment and risk estimation.

The main objective of this paper is to develop a generic framework for bow-tie analysis under uncertainties in the sustainable enterprise.

Bow-tie analysis is an integrated probabilistic technique that analyzes accident scenarios in terms of assessing the probability and pathways of occurrences [4]. It is intended to prevent, control and mitigate undesired events through development of a logical relationship between the causes and consequences of an undesired event [3].

2.1. BASIC ELEMENTS

A bow-tie diagram has five basic elements. The relationships among these elements are, Fig. 1:

• Causes: The causes are the fundamental reasons that result in failures, malfunctions, faults, or human error at a component level. These reasons are termed basic events (BE).
• Fault tree (FT): FT graphically represents the path of causation leading to an undesired event.
• Intermediate Events (IE): The Intermediate result, the result of AND/OR gates’ BE;
• Critical event (CE): In a bow-tie diagram, the top-event of a FT is the initiating event for an ET. This event is called a critical event in the bow-tie.
• Event tree (ET): ET sequences the possible consequences of the CE considering a dichotomous barrier (i.e., success/failure, true/false, or yes/no) of safety function (e.g., alarm, automatic shutdown) or accident escalation factor (e.g., ignition, explosion, dispersion).
• Outcome events (OE): The final consequences resulting from systematic propagation of a CE through the barriers are named outcome events [1].

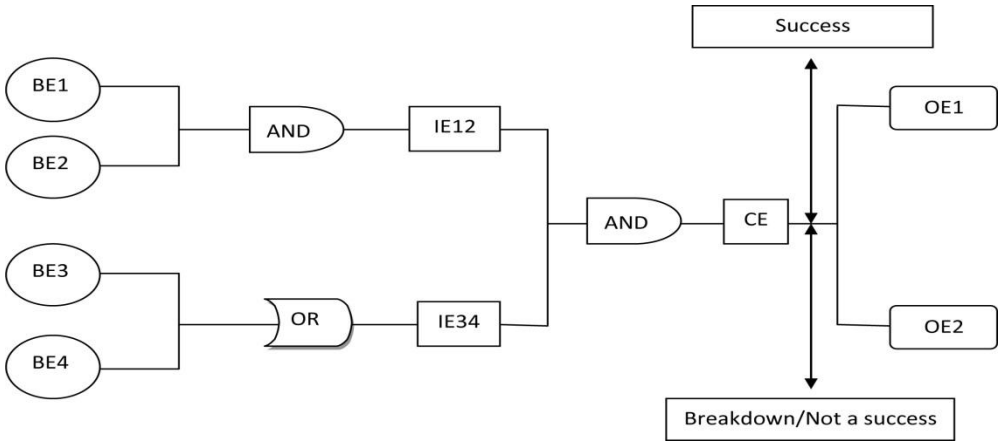

Fig. 1 Elements of a "Bow-tie" diagram

2.2. A FRAMEWORK FOR BOW-TIE IN THE SUSTAINABLE ENTERPRISE

A generic framework for bow-tie analysis has been proposed in Fig. 2 that can handle data and model uncertainties in risk analysis in sustainable enterprise.

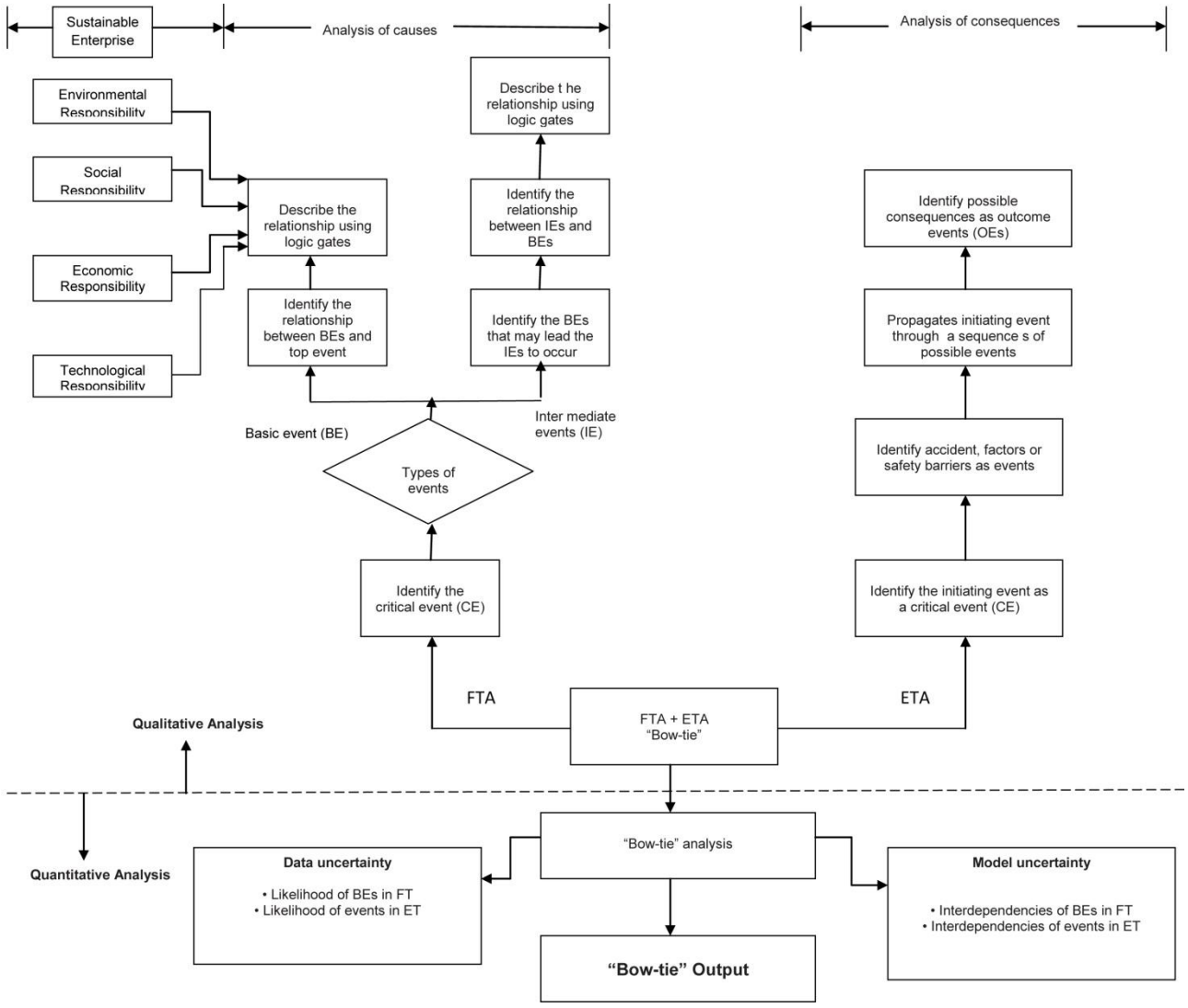

Fig. 2 Proposed framework for Bow-tie analysis in sustainable enterprise

This framework for the risk analysis starts with the description of the causes within the four responsibilities of the sustainability, and then it continues with the description of the relations between these causes by using logical gates and in the end obtaining the final critical event (CE). Also the possible consequences that may take place as an output of the event and then the accidents and the safety barriers as possible events are identified; and finally the identification of the critical event (CE). In the left side is the Fault Tree development and in the right side is the Event Tree development. Thus the link between FTA and ETA of Bow-tie was done. In the end the outputs: likelihood of CE, likelihood of OEs, Sensitivity Analysis and Contribution of BEs are obtained. The correct risk assessment leads towards a sustainable enterprise.

4. CONCLUSIONS

Bow-tie analysis is a relatively new tool for safety assessment and risk analysis of a system. Uncertainties in input data and model adequacy for bow-tie analysis are still a major concern and may mislead the decision-making process.

Future research directions involve: the development of modeling based on emerging risks, making an application using the expert system using VP-Expert generator and conducting exploratory research to define and implement safety / security culture in organizations.

5. ACKNOWLEDGMENTS

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