Archives of Current Research International

12(2): 1-6, 2018; Article no.ACRI.32857
ISSN: 2454-7077

Engineering Risk and Decision Analysis

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Authors' contributions

This work was carried out in collaboration between all authors. Author OPC designed the study, performed the analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors OBS and OUO managed further analyses and part of the literature searches of the study. Author UDC managed the remaining literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACRI/2018/32857
Editor(s):
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Complete Peer review History: http://www.sciencedomain.org/review-history/23119

Original Research Article

Received 20th March 2017
Accepted 5th February 2018
Published 10th February 2018

ABSTRACT

Engineering systems design and analysis is dependent on the ability to analyse the system in the context of uncertainties in their performance. Engineering systems design evaluates the reliability of normal operations, the risk of normal operations, appropriate decisions to maintain reliability and optimal performance. Many industries are scouting and employing engineering professionals with appropriate understanding and knowledge of engineering systems design and risk management. This will significantly increase the number of engineers with the professional skills in engineering systems design and risk management in engineering. This research reveals in details the areas of risk assessment, risk management, decision and engineering analysis. Risks have been identified. The decisions to be taken to avoid such risk from occurring have been provided by bringing in

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advanced analytic techniques. Employment of the appropriate advanced analytical techniques and professionals in the system will advance decision making and risk assessment and consequently risk management.

Keywords: Engineering; risk; decision; analysis; statistics; probability; assessment; vector quantity and management.

1. INTRODUCTION

Engineering systems design and analysis are becoming much more dependent on the ability of the engineer to analyze the system in the context of uncertainties in system performance, evaluation of the reliability of normal operation and the risk of off-normal operation, and then taking the appropriate decisions to maintain reliability and optimal performance. As a result, many industries (e.g., chemical, construction, transportation e.t.c.) are looking for graduates with appropriate understanding and knowledge in these areas. Hence, we propose to enhance our engineering curriculum in these areas by developing new courses to cover this area.

In order to properly prepare our students to be productively engaged in risk-based decision-making in industry, we must provide them with instruction in several areas, specifically including:

- Statistics and probability
- Modern uncertainty analysis
- Decision analysis
- Probabilistic reliability and risk assessment (PRA)
- A practicum with realistic examples, projects and seminars

1.1 Background

The risk is defined as a coincidental or condition concerning such a probability [1]. For the sociologist, Niklas the term 'risk' is a neologism that appeared with the transition from traditional to modern society [2]. "In the Medium Centuries, the word risicum stood cast off in highly specific circumstances, beyond all sea line of working addition to its resulting authorized glitches of harm and injury" [3]. In the vernacular languages of the 16th century, the words rischio and riezgo were used. This was introduced to continental Europe, through interaction with Middle Eastern and North African Arab traders. In the English language, the term *risk* appeared only in the 17th century and appears to trade in from mainland Europe. When the terminology of risk took ground, it replaced the older notion that thought in relations to upright as well as ruthless affluence. Scenario analysis matured during Cold War confrontations between major powers, notably the United States and the Soviet Union. It became widespread in insurance circles in the 1970s when major oil tanker disasters forced a more comprehensive foresight. The scientific approach to risk entered finance in the 1960s with the advent of the capital asset pricing model and became increasingly important in the 1980s when financial derivatives proliferated. It reached general professions in the 1990s when the power of personal computing allowed for widespread data collection and numbers crunching. Governments are using it, for example, to set standards for environmental regulation, e.g. "conduit examination" as practiced by the United States Environmental Protection Agency.

1.2 Definitions of Risk

The risk is defined as the impact of uncertainty on goals. This explanation of uncertainties involves trials and decisions triggered by ambiguity or a deficiency of facts. It is likewise comprised of the unenthusiastic and optimistic impacts on the aims. Sundry descriptions of risk occur in communal usage; however, this description was industrialized by a global group, signifying over thirty (30) republics and is founded on the contribution of numerous professionals.

1.3 Goals and Outcomes

The primary goal of this research is to significantly increase the number of engineers with an understanding of uncertainty, risk, and risk-based decision-making. Many of our industries (e.g., Midwestern utilities such as Exelon and Dominion) have identified a need in this area and cannot meet the need with current graduates. Hence, they are forced to do their own training. Such training programs, while important to emphasize plant-specific issues, can more efficiently provide the fundamentals to engineering students as part of their academic training at engineering schools and colleges. The nuclear industry can also benefit from this program by providing the key educational background that their new hires need on fundamental issues as they are integrated into their engineering curriculum.

1.4 Statistics and Probability

Risk conveys a lot of dissimilar meanings. There are several official approaches used in the measurement of risk.

Even though statistical guesstimates stand accessible, in several circumstances, the risk is allied through uncommon failures of certain kind and data records may be meagre. Habitually, the likelihood of an undesirable occurrence is appraised by using the rate of recurrence of previous analogous trials or by occurrence tree approaches, but odds for uncommon failures possibly will be problematic to guesstimate if an incident tree cannot be framed. This makes risk assessment problematic in precarious manufacturing activities. For instance, nuclear energy where the frequency of failures is rare and harmful, consequences of failure are plentiful and simple.

Statistical approaches may also necessitate the routine of a price tag function which in turn may necessitate the control of the cost of forfeiture of a human life. This is a difficult problem. One approach is to ask what people are willing to insure against death but as the answer depend very strongly on the circumstances, it is not clear whether this approach is effective.

In statistics, the symbolization of risk is frequently modelled as the predictable value of a disagreeable result. These cartels the possibilities of a number of likely happenings and various assessment of the equivalent harm into a lone value. The simplest case is a binary probability of coincidence or no coincidence. The allied formula for computing risk is as shown below:

$$Total\ Risk\ = Probability\ of\ the\ risk\ occurring \times the\ loss\ involved.$$

1.5 Risk Analysis

It is the science of risks, their probability and evaluation. Risk analysis may refer to:

- Quantitative risk analysis
- Probabilistic risk assessment
- Risk management
- Risk management tools
- Certified risk analyst
- Food safety risk analysis

1.6 Risk as a Vector Quantity

Hubbard [4] Reasons that are defining risk as the product of influence and prospect guess (perhaps inaccurately) that the verdict fabricators are risk unbiased. Only for an unbiased risk person is the "sure monetary correspondent" exactly equal to the product of the probability of the loss and the amount of the loss. For illustration, an unbiased risk person would deliberate 20% gamble of winning ₦1 million accurately equivalent to ₦200,000 (or a 20% gamble of losing ₦1 million to be accurately equivalent to losing ₦200,000). Nevertheless, utmost verdict fabricators stand not essentially risk unbiased and would not contemplate these comparable varieties. This offered intensification to Prospect philosophy and collective prospect philosophy. [5] Suggests that risk is a type of "vector quantity" that does not flop the likelihood and enormousness of a risk by presuming whatever about the risk broadmindedness of the verdict maker. Risks are purely designated as a set or role of thinkable loss quantities respectively related to precise possibilities. How this selection is misshapen into a solo value cannot be completed pending the risk forbearance of the decision maker is measured.

Risk can be both negative and positive, but it tends to be the negative side that people focus on. This is because some things can be dangerous, such as putting their own or someone else's life at risk. Risks concern people as they think that they will have a negative effect on their future.

1.7 Risk Assessment

Risk assessment is a phase of a risk management system. Risk assessment is the willpower of quantitative or qualitative rate of risk linked to a concrete status quo and a familiar hazard. Quantitative risk assessment necessitates calculations of two mechanisms of risk; the degree of the potential loss (L), and the prospect (P) that the loss will happen. Risk assessment comprises of an objective estimation of risks in which expectations and uncertainties are measured and offered. Fragment of the exertion in risk management is that magnitude of the capacities in which risk assessment is troubled that is, prospective loss and probability of an event can be very tough to quantify. The casual of inaccuracy in assessing these two notions is bulky. The risk with a hefty prospective loss and a low probability of happening is regularly cured contrarily commencing one with a little potential loss and a tall probability of occurring. In concept, mutually both are of nearly identical primacy, but in practice, it can be very challenging to manage when confronted with the insufficiency of assets, particularly time, in which to conduct the risk management technique.

1.8 Fear as Intuitive Risk Assessment

From the existence, people depend on their fright and unwillingness to be preserved out of the peak extremely unidentified situations.

Gavin [6] Argues that true fear is a gift. It is a survival signal that sounds only in the presence of danger. Yet unwarranted fear has assumed a power over us that it holds over no other creature on Earth. It need not be this way.

Risk possibly will be believed to be the technique we jointly ration and portion this "exact anxiety", a synthesis of lucid uncertainty, unreasonable anxiety and a set of unquantified favoritisms from our peculiar understanding.

1.9 Engineering Risk Analysis and its Application to Human and Animal Epidemiology, as Well as to Food Safety

Fundamentally, in risk assessment, we define risk as a function of both the likelihood of something bad happening and the severity of that outcome. For example, [7], defined risk as involving both uncertainty and some kind of loss or damage. Emphasis will be laid on the uncertainty quantification rather than the consequences. Risk assessment provides “A medium to illustrate and diminish indecision or improbability to support our aptitude to apportion with upheaval through risk management” [8]. Fundamentally, risk management is a decision process. It is a social and political process by which people decide what to do while taking into account a wide variety of factors. Risk assessment is an input to the process and provides technical information to inform decision making in light of all these other considerations and value judgments. The Center for Risk and Economic Analysis of Terrorism Events(CREATE), based at the University of Southern California and funded by the Department of Homeland Security, has defined a process that includes four basic modelling steps:

- The first step is risk assessment,
- The second step is consequence assessment (that is, how bad the outcome could be, once we know the likelihood of something bad happening).
- The third step refers to what types of emergency response actions are available to help mitigate the consequences.
- Finally, the economic assessment is done, based on the severity of the final consequences (taking into account the emergency response; this step determines the total economic impact of the event above and beyond the health or mortality consequences), and so completes the list of input needs that a decision maker might have.

The overall goal of risk assessment is to be reliable and fully defendable (American Industrial Health Council and others, 1989). In particular, it should provide a comprehensive statement of the current uncertainties, so that if you have a good risk assessment in hand, there should be a small chance of “after-the-fact surprises.’’

Therefore, a good risk assessment should have large uncertainty bounds if the true uncertainties are large, rather than focusing on the best estimate and then finding out later that the true situation was much better or worse than the best estimate. The intent is that a good risk assessment "explicitly and fairly conveys scientific uncertainty, including a discussion of research that might clarify and reduce the degree of uncertainty” (American Industrial Health Council and others, 1989). Once we know how big the uncertainties are and where they arise in the risk assessment, we can use this knowledge to prioritize decision making about where to spend our research dollars to reduce risk in the long term, as well as which protective measures should be put in place in the short term.

1.10 Risk Management

Risk management is the identification, valuation and prioritizing of risks monitored by corresponding and efficient solicitation of resources to abate, display, and governs the probability or effect of luckless trials or to exploit the comprehension of prospects. Risks can originate from improbability in project failures, legal obligations, acclaim risk, accidents, natural bases and calamities as well as thoughtful attack from an opponent, or impulsive root-cause.

1.11 Decision Analysis

Decision analysis (DA) is the study that consists of the philosophy, theory, methodology and skilled practice crucial to lecture the significant resolutions in a proper mode. Decision analysis comprises numerous processes, approaches and apparatuses for ascertaining, clearly representing and properly evaluating significant features of a decision, for suggesting an optional course of action by putting on the extreme anticipated efficacy axiom to a well-formed exemplification of the decision. And for decoding the proper sign of a decision and its conforming recommendation into insight for the decision maker and further interested party.

2. METHODS

The term decision analysis was coined in 1964 by Ronald A. Howard, who since then, as a professor at Stanford University, has been instrumental in developing much of the practice and professional application of DA. Graphical representation of decision analysis problems commonly uses influence diagrams and decision trees. Both of these tools signify the replacements accessible to the decision maker, the uncertainty decision making face, and estimation measures signifying how well objectives are achieved in the end. Uncertainties are represented by probabilities and probability distributions. The decision maker's approach to risk is symbolized by useful functions and their assertiveness to trade-offs among contradictory goals can be made using multi-attribute significance functions or multi-attribute utility functions. In some cases, utility functions can be replaced by the probability of achieving uncertain aspiration levels. Decision analysis supports selecting that decision whose penalties have the extreme expected utility (or which exploit the odds of attaining the inexact ambition level).

3. RECOMMENDATION

I recommend that more discoveries related to this work should be made. Since there are still bound to be more risks experienced, it is very important that there should be research work so as to discover the possible risks that could occur and provide means of managing them before they occur. Also, more work should be done on this topic to discover the other related sub-topics.

4. CONCLUSION

To accomplish this ambitious goal, Engineers who are professionals in decision making, risk management and engineering analysis will be engaged in an engineering issue, building on the engineering insight, possibilities to analyze decision via various engineering ideologies formerly used for designing more meaningful items like bridges and buildings. This insight was hitherto functional of engineering software, which is alternative nice of imperceptible engineered artifact with important merits. The practice of a graphic design language signifying decisions is emergent as an imperative component of decision engineering. Engineering decisions offer an intuitive communal language gladly agreed by all decision contributors. However, if engineering risk and its decision making were anticipated, predicted, controlled and managed by engineering professionals, there will be a high benefit of risk management and excellent decision making in achieving engineering goals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/23119