International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:12, No:10, 2018

# Tools and Techniques in Risk Assessment in Public Risk Management Organisations

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***Abstract*—**Risk assessment and the knowledge provided through this process is a crucial part of any decision-making process in the management of risks and uncertainties. Failure in assessment of risks can cause inadequacy in the entire process of risk management, which in turn can lead to failure in achieving organisational objectives as well as having significant damaging consequences on populations affected by the potential risks being assessed. The choice of tools and techniques in risk assessment can influence the degree and scope of decision-making and subsequently the risk response strategy. There are various available qualitative and quantitative tools and techniques that are deployed within the broad process of risk assessment. The sheer diversity of tools and techniques available to practitioners makes it difficult for organisations to consistently employ the most appropriate methods. This tools and techniques adaptation is rendered more difficult in public risk regulation organisations due to the sensitive and complex nature of their activities. This is particularly the case in areas relating to the environment, food, and human health and safety, when organisational goals are tied up with societal, political and individuals' goals at national and international levels. Hence, recognising, analysing and evaluating different decision support tools and techniques employed in assessing risks in public risk management organisations was considered. This research is part of a mixed method study which aimed to examine the perception of risk assessment and the extent to which organisations practise risk assessment' tools and techniques. The study adopted a semi-structured questionnaire with qualitative and quantitative data analysis to include a range of public risk regulation organisations from the UK, Germany, France, Belgium and the Netherlands. The results indicated the public risk management organisations mainly use diverse tools and techniques in the risk assessment process. The primary hazard analysis; brainstorming; hazard analysis and critical control points were described as the most practiced risk identification techniques. Within qualitative and quantitative risk analysis, the participants named the expert judgement, risk probability and impact assessment, sensitivity analysis and data gathering and representation as the most practised techniques.

***Keywords*—**Decision-making, public risk management organisations, risk assessment, tools and techniques.

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## I. Introduction

THE public sector has been criticised in numerous studies for relatively poor efficiency and productivity levels in comparison to other sectors [1]-[3]. Regrettable incidents such as the West London Grenfell Tower fire in 2017; the crises regarding the use of peanuts and almonds rather than cumin seeds in the UK food supply system in 2015; the horsemeat scandal in 2013 across Europe; the Irish pork crisis in 2008; and the South Wales E.coli tragedy in 2005 have extremely damaged the public authorities' reputation. Studies within the European Academy [4] outlined the key issues regarding inadequate risk assessment practices with inappropriate use of tools and techniques being identified as contributing to systemic failures. As Shenkir and Walker [5] note, inappropriate adaptation of tools and techniques (which were deemed to be not fit for the purpose) can lead to the underestimation of potential impact and, in the eventuation of harm occurring, cause irreparable damages to human health and safety at national and international levels.

Risk assessment practices and related tools and techniques have been extensively discussed within regulatory agencies and academia. Nevertheless, despite extensive debate in these circles, such discussions have largely failed to solve the conundrum of how best to adopt techniques to best match the situations that organisations face [6], [7]. Recognised standards do address the use of tools and techniques in a general context in relation to organisational and operational levels but there is no specification with regards to specific strategies or particular project characteristics. Scholars working in the field of risk assessment have suggested that the required level of resources to adopt holistic risk assessment tools and techniques over a sustained period of time are unrealistic for most organisations. As such it is largely beyond the capability and affordability of many institutions and agencies to accommodate such provision [8], [9]. From an industrial point of view, the distinctive institutional attitudes in risk assessment can lead to utilisation of different risk management strategies which can be inconsistent within or cross domains. This potentially affects not only organisational efficiency but also produces deleterious effects on communities and individual welfare [10].

The adequate use of tools and techniques within risk assessment can help public organisations make better decisions on community safety based on calculated risks, and potentially improve systems of accountability which are much needed in the light of incidents such as Grenfell Tower. More considered and informed use of tools and techniques of risk identification and risk analysis can improve the accuracy of

outcomes in the risk assessment process [11] which can produce a real benefit in terms of the work of public institutions. Such use of effective risk assessment techniques is highly influenced by institutional characteristics. Rostami et al. [8] have indicated that the organisational internal factors such as system, level of resources, and culture - which determines the organisational characteristics, are more influential than the external requirements in the process of adopting tools and techniques in risk assessment. They specified that the bureaucracy of management in resource allocation and vertical hierarchy system could negatively affect the use of tools and techniques.

A study of effective risk management mechanisms [12] reported that more than 35% of public institutions do not have risk assessment mechanisms in place to evaluate risks. This research also highlights that public sector organisations are not generally aware of the risk assessment approaches and can suffer from lack of up to date knowledge and understanding of the most efficient techniques. In public risk regulation organisations, particularly in the environment, food, and human health and safety sectors, the improper adaptation of tools and techniques may lead to irreparable damages, and ruin organisational reputations. Hence, recognising, analysing and evaluating different decision support tools and techniques in assessing risks in public risk management organisations are crucial. In fact, due to the public risk regulation organisations' characteristics, it is vital to adopt and practise the most appropriate techniques to meet the public health and safety legislation and standards.

The intention of this study is to identify and assess the most frequently-used tools and techniques in risk assessment within public risk management organisations. It also evaluates the pros and cons of the identified techniques to determine the influence of organisational characteristics on risk assessment strategy plans.

This study presents the first part of an ongoing research project which aims to develop a framework to support public risk regulation organisations in future risk assessment and management processes. In particular, the study will seek to understand the interplay between different quantitative and qualitative tools and techniques currently in operation and the possibilities for future development through synthesis. The knowledge gained will facilitate decision-making at senior management level, and consequently, will influence the sustainability, productivity and efficiency of organisations, and enhance the organisational reputation.

## II. Risk Assessment Process

The risk assessment process is constituted by a systematic evaluation of an activity or project that organisations carry out at work to control and mitigate risks. Risk assessment comprises the process of identifying, analysing, evaluating and controlling risks [13]. It provides detailed knowledge that can enable understanding of probable risks, their causes and consequences.

Risk identification is the first step of risk assessment and entails the process of finding, recognising and recording risks [13]-[15]. Risk identification answers questions such as what can occur; which could affect organisations' objectives; and what the reasons are behind that. This process helps to find, recognise and record risks and facilitates the foundation for risk analysis [13]. If risks are not identified accurately they cannot be managed appropriately [16]. Risk identification is a major challenge for many organisations. Complexity of systems, interaction of practitioners, technology and other organisational factors such as communication and training, make the risk identification phase complicated and challenging [17]. Identifying risk in a complex system requires a clear definition of risk (internal and external threats and opportunities) as well as a structured strategy [18]. In the context of public health and safety, 'risk' means "the probability of harmful event such as death or injury from an activity or accident at a major hazard". The word 'hazard' is used to mean a situation with potential to cause harm to people and society, but it does not imply whether the likelihood is low or high [19]. In the context of food, safety risk is defined as

> "a function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food" [20].

Generally, in the subject of human health and safety, the word 'risk' is considered as a threat which delivers a negative signal.

After risk identification, the identified risks are prioritised through the risk analysis process based on their probability and impact. This 'risk analysing system' [21] provides inputs for evaluation and decision-making processes to select risk response strategies. Referring to Baccarini and Archer [22], due to lack of time and resources, it is not possible to address all identified risks in the risk assessment process; therefore, risk analysis helps to evaluate risks with high level of probability and impact. Nevertheless, serious and fatal risks may simply being ignored as a result of extreme catastrophic events when the probability of occurrences is low [23]. This is highlighted as an essential problem of some risk analysis methods [21]. Therefore, in the subject of human health and safety, there are risks which need to be addressed even with low probability of occurrences since they are serious threats to the environment and human life.

Failures in risk identification and analysis source miscalculations and inadequacy in the whole risk assessment and management processes, and affect the achievements of organisational objectives [6]. There are various tools and techniques to facilitate the processes of risk identification and risk analysis. Appropriate and efficient tools and techniques can satisfy both the philosophical and methodological requirements of stakeholders and decision makers through the risk assessment process.

In enterprise risk assessment many organisational factors such as structure, objectives, strategies, culture, size, resources, amount of investment, knowledge and expertise of personnel, risk maturity of staff, the information available, range and type of potential risks may influence the choice of tools and techniques [15], [24], [25]. These factors could

determine the practice of qualitative, quantitative or combination of both methods. For this purpose, it is crucial for organisations to not only know the most appropriate information to use in this process but also to understand the advantages and disadvantages of the process; the complexity in evaluation and decision-making; and the appropriate alternative methods in order to evaluate risks [13], [26], [27]. Hall [21] confirmed that using different tools and techniques could result differently in risk scoring which makes the justification of risk assessment process difficult. Therefore, realising 'justifiable', 'comparable' and 'repeatable' tools and techniques is essential.

To highlight and evaluate the most widely-used tools and techniques, this study considered the British Standard [13] category of techniques for risk identification and risk analysis. The question of major relevance to public risk regulation organisations with regard to the practice of risk assessment tools and techniques is: what are the tools and techniques used for risk identification and risk analysis and how effective are they?

## III. Tools and Techniques

The process of assessing risk involves different stages of identification, analysis and evaluation which need to be facilitated by the use of tools and techniques. Within enterprise risk assessment, tools and techniques are mainly influenced by organisational factors.

Referring to literature and bodies of knowledge [13], [15], [24], [25], [28], the most widely-used tools and techniques in risk assessment (both identification and analysis phases) in engineering and construction industry are explained as: check list and SWOT analysis, expert judgement, documentation reviews, hazard analysis and critical control points (HACCP), scenario analysis, and business impact analysis. Though, the most practised tools in health care system and patient safety are explained as event tree analysis (ETA), fault tree analysis (FTA), and failure mode and effect analysis [29].

There are however other techniques which can be implemented in the risk analysis stage which include Root Cause analysis, Monte Carlo simulation, Bayesian statistics and Bayes Nets [8], [30]. Recognising and practising tools and techniques within enterprises requires a great degree of awareness, effort, experience and substantial investment [8], [31]. Rostami et al.'s [24] research also highlights that size of organisations potentially influences the degree of resources which directly affects the selection of risk assessment tools and techniques. Hence, depending on the level of available information and organisational resources (technical, knowledge, time, etc.), either quantitative, qualitative or semi-quantitative methods will be selected through enterprise risk assessment.

Quantitative methods "estimate practical values for consequences and their probabilities, and produces values of the level of risk in specific units defined when developing the context" [13].

Quantitative techniques necessitate a sufficient level of information in order to make the statistical analysis possible. Quantitative methods include: quantitative risk analysis and modelling i.e. sensitivity analysis; modelling and simulation i.e. Monte Carlo analysis; data gathering and representation techniques i.e. probability distribution functions; knowledge based risk assessment; etc. It is not always likely or necessary to consider a comprehensive quantitative analysis due to the lack of availability of sufficient information and resources. Therefore, qualitative or semi-quantitative methods through experts can be replaced. The qualitative method principally estimates the probability and significance of risks without any actual statistical data. In this method, risks are analysed based on their possible extent of values. Practitioners primarily use the risk-rating approach to indicate the risks' probability and impact levels. The probability and impact are combined in order to evaluate the level of risks for decision-making according to the qualitative measures and criteria, while attitude of practitioners influence the assessment process [32]. This is because of the risk variables that can be assigned different range of values based on people's judgment and assessment. Examples of qualitative risk assessment methods are: risk probability and impact assessment; expert judgment; risk data quality assessment; probability and impact matrices; expected value; etc.

The semi-quantitative method is a semi-numerical process in which probability and impact are being rated and combined by using a formula. A very simple and common method of assessing the severity of a risky event in this method is to multiply the probability of an event by its anticipated impact [33]. The development of the fuzzy techniques by Carr and Tah [34] helped to mathematically model qualitative analysis. However, due to the complexity (algorithms with certain procedures) in fuzzy technique, it is not common for organisations to use such method in their risk assessment process [35]. Utilising complex tools in risk assessment also makes the understanding of principles and assumptions difficult for non-specialists in the field [36]. Quantitative methods such as Monte Carlo simulations and Markov analysis also deliver such complexity due to the involved mathematical calculations. The results from quantitative risk assessment support the decision-making process in order to demonstrate the risk associated with organisational activities are acceptable or not. Referring to the document published by the Health and Safety Executive [19], the quantitative calculation by using the past data is essential to make prediction; however, the data is not likely to demonstrate all possibilities. Using mathematical models in prediction would perhaps be realistic in certain situations in order to estimate the rate of hazards together with their related aftermath activities. This estimation provides information for risk evaluation and further decision-making.

## IV. Research Methodology

This research covers the pilot study which preceded the main project which aims to examine the perception of risk assessment and the extent to which organisations use tools and techniques in risk assessment. The adopted methodology includes a broad literature review; sampling and data

collection; and data analysis. The paper presents results from the questionnaire survey within six public risk regulation organisations in the area of the environment, food, and health and safety. The research carried out from 15th March to 5th July, 2017 and included risk assessment professionals. The questionnaire helped to assess the range of risk assessment tools and techniques within the risk assessment process. It principally focused on organisational and operational levels of risk assessment rather than detailed technical risk assessment. This study did not obtain the technical details on specific risk assessment process such as the chemical and/or microbiological risk assessment.

The questionnaire was based on both closed and open-ended questions to gain experts' experience and knowledge on risk assessment tools and techniques. The results of the research will support the main study to evaluate and prioritise the most practised decision support tools and techniques in risk assessment to develop a framework for risk assessment. The developed framework will facilitate implementation of existing and future assessing and managing risks in the human and public health areas and contribute towards improving the effectiveness of risk assessment approaches in decision-making process. For the purpose of this pilot study, data was collected through an emailing questionnaire with the industrial partners.

Based on the British standard [13] and the standing literature [25], [32], [37]–[41], a list of applicable tools and techniques for both risk identification and risk analysis were determined. The list comprised of 26 tools for risk identification and 12 tools for risk analysis (both qualitative and quantitative methods of risk analysis). This assisted to establish the research questionnaire, also made clear the results of the literature review, and added scope to the research. The questionnaire was based on three sections. The first section included general information about the organisations' (e.g. name, area of work, sector in which they operate in and respondent's position). The second section considered tools and techniques in risk identification and risk analysis. A list of tools and techniques was provided to ask participants to scale the most practiced tools in risk identification and risk analysis. The questionnaire was designed based on the Likert scale '5-point frequency scale' from "not used at all" to "used to a very large extent". Participants were also asked to explain the reasons behind adopting and practicing a particular tool or technique. They were required to add the name(s) of any other tool or technique that was not listed in the table. Organisations were also questioned on risk assessment software package(s).

The collected data were analysed by deploying both quantitative and qualitative methods. The quantitative data were analysed by using Statistical Package for the Social Sciences (SPSS) version 23. The initial intention was to utilise factor analysis for exploring data. Factor extraction assists to establish the smallest number of required factors to signify the interrelationships between a set of variables [42]. It is based on a variety of different approaches and requires at least 100 factors to be analysed. In this pilot study, because of the sample size the 'frequency' measure was replaced to evaluate the most practiced tools and techniques in organisations along with the rate of their practices.

## V. Research Findings

**Presently used risk identification techniques in public risk regulation organisations** - The results of the study demonstrate that the most presently practised techniques in risk identification in public risk management organisations are primary hazard analysis, brainstorming, hazard analysis and critical control point.

**Primary Hazard Analysis (PHA)** - Primary hazard analysis (PHA) helps to identify the risky events which could cause damage to activities of a system. PHA was generally implemented at the early stage of a project development when little is known about operating processes. This tool is a precursor to further investigation about a specific system which also helps to prioritise risks of the system for further analysis. It is mainly practised when possibility of using other techniques is restricted due to the organisational lack of available information.

The PHA technique appeared as the most practiced risk identification tool by the public risk management organisations. One of the organisations from the food safety sector explained that this tool is used to identify the most important risks/hazards in circumstances such as risks of certain storage conditions. An organisation from the health and safety sector stated that this tool supports their firm "to recognise potential major accident hazards". The survey results specified the strengths of this tool as its practicality when limited information is available, and helping to consider risks at initial development of a system. PHA has its own limitations. PHA makes available 'preliminary information' not detailed data on risks and information on best possible preventive approaches and it is not 'comprehensive' [13].

**Brainstorming** - Brainstorming delivers a motivating 'free-flowing' discussion between expert people to identify probable related risks, failure modes, and criteria and principles for decisions [13]. To implement the technique, it is necessary to facilitate the group discussion effectively by means of embracing stimulation at the beginning, or periodic encouragement of the involved people into other applicable situations to receive the issues arising from the discussion. The technique can provide a different range of outcomes that depends on the stage in which risks are being assessed. For example, the output could be a list of risks and existing controls.

The brainstorming technique was the second most practiced risk identification technique by the public risk management organisations. The main reason behind implementing this technique in food safety organisations is the identification of risk factors and prioritisation of microbiological hazards in several products. The firms from the health and safety sector explained that the brainstorming helps in policy development in establishing the risk assessment process. Lyons and Skitmore [28] confirmed that the technique is mainly practised in projects in both formal (more structured) and informal (less

structured) settings to establish the risk assessment framework.

Like other techniques, brainstorming has strengths and limitations. The technique helps organisations with the easy set up process, providing opportunities to encourage imagination to identify new risks and innovative solutions, and involving important stakeholders to support the overall risk communication. However, it conveys weaknesses which include: possibility of contribution of unskilled and unexperienced participants which can influence the effectiveness of discussions; it is not easy to prove the process as being comprehensive since it is fairly unstructured; it is possible that the discussion is being dominated by some people while others stay quiet despite having valuable thoughts to share.

**Hazard Analysis and Critical Control Point (HACCP) -** This study indicated the hazard analysis and critical control point (HACCP) as the third most practiced risk identification technique. The technique provides a structure for identifying risks and preparing appropriate control measures for all applicable phases of a risk management process. It helps to protect projects of threats and to sustain 'the quality reliability and safety' of organisations' activities. The technique ensures threats are mitigated by controlling the process instead of reviewing the outcome [32].

According to BS EN3010 [13], HACCP was originally established 'to ensure food quality for the NASA space program'. Currently, the technique is the first option of organisations in the food industry. It helps risk regulators in the physical, chemical or biological toxins identification process. More recently, the technique is also being used in the pharmaceuticals manufacturing and medical devices (ISO 22000). A participant from the food safety sector indicated that according to the self-checking guides within the industry all organisations should consider and practise the HACCP technique to control risks of products.

Participants specified the strengths of the technique as: being a structured process with focus on identifying risks; minimising threats and documenting evidence for quality control; controlling risks throughout the process and not at the final stage; being practical in terms of identifying threats caused by human actions and the method of controlling threats at the point of establishment or afterwards. However, HACCP has its own limitations. In order to provide inputs to the method, all risks need to be recognised, well defined, and their consequences are being understood. It is also essential to define applicable controls to the technique to avoid of technical barriers [43]. Technical barriers embrace perceptions, attitudes and practices that adversely influence the recognition of the HACCP concept and consequently the effective implementation and maintenance of the HACCP criteria [44].

## VI. Presently Used Qualitative Risk Analysis Techniques in Public Risk Regulation Organisations

**Expert Judgement (EJ) -** The study derived the Expert Judgment as the most practised technique in qualitative risk analysis. The technique is widely used in risk management activities for analysing external and internal risks and uncertainties. The participants explained that expert judgement is being used in all risk assessment stages. Risk analysts from the health and safety sector highlighted the organisational policies as the key practising factor of the technique. They use the technique within in-house workshops to assess the impact of the identified risks. In other industries such as manufacturing and construction, organisations use the technique because of its outcomes accuracy, uncomplicated process, and inexpensive process in comparison to other costly techniques like diagramming [24].

The results obtained from EJ rely on the experience and knowledge of individuals or groups of experts in the field [45]. Using expert views in a structured and systematic process helps in estimating probability by using available information such as historic data, system specific, experiments, etc. [46]. Methods such as the Delphi technique, paired comparisons, category rating and absolute probability judgements are utilised by the expert judgment technique. Hora [47] stated that the EJ technique is, however, a challenging process due to the experts' different approach in calculating risks.

**Risk Probability and Impact Assessment (RPIA) -** The second most practiced qualitative risk analysis technique, within the public risk management organisations, is Risk Probability and Impact Assessment (RPIA). This technique is used to prioritise the involved risks of projects and products. After the risk identification process, a scoring system individually prioritises the identified risks with regard to their impact and probability rates. This technique is used to develop a quality assessment score at the net risk level. The net risk level of threats or opportunities is known as an uncomplicated average of the two quality assessment scores. Based on a coding classification and the net risk level, practitioners recognise the uncertainties' average net.

In this study, the technique is mainly practised by the health and safety, and food safety organisations for their regulatory purposes. A participant from the food safety industry stated,

> "The technique helps to evaluate the probability and impact of hazardous events". He defined the food safety risk based on the severity of a hazard to be present in the food and its likelihood. This technique supports the organisation's decision-makers to provide more science-based decisions, and takes into account the food safety risks among the whole food chain [48]. Another participant indicated the use of the technique in the organisational risk assessment process. He stated, "The technique is practised for some specific regulatory issues such as chemicals pesticides and biocides".

## VII. Presently Used Quantitative Risk Analysis Techniques in Public Risk Regulation Organisations

**Sensitivity Analysis -** The first most practised quantitative risk analysis technique within public risk management organisations is sensitivity analysis. The development of sensitivity analysis helps to control uncertainties with the least possible impact on organisations' objectives. Using the

technique assists organisations to determine the significance and magnitude of a risk according to changes in each input factor. It supports organisations to predict the consequences of a decision [49]. Sensitivity analysis facilitates the accurate data identification process through less sensitive data with less effect [13]. However, the technique mainly relies on unjustified assumptions of model linearity and additivity [50].

Most of the involved public health and safety regulatory organisations described the technique as an effective tool in risk assessment. It helps them to assess the impact of risks through the quantitative risk analysis modelling. It provides a simulation analysis in which key quantitative assumptions within organisational decisions are changed systematically to evaluate their effect on the outcome. The results specified the popularity of the technique in complex risk modelling systems in different disciplines.

**Data gathering and representation techniques - Probability Distributions** - The data gathering and representation techniques principally assess risks based on the qualitative historical and experiential data. These techniques use the collected qualitative data to quantify the likelihood and impact of risks that affect activities. The quality of the collected data in these techniques highly relies on the type and form of practiced probability distributions [13].

This set of techniques is the second most utilised technique by public risk management organisations. A participant from the health and safety risk regulatory organisations specified the use of technique to estimate 'failure frequencies'. He stated that failure frequencies in risk assessment are established on values derived from the major hazards assessment unit. In this process, the risk analyst needs to decide whether or not the failure rate is appropriate for the organisational assessment. If it is not suitable, then further work should be considered to derive an appropriate failure rate. The research participants did not directly specify the type of probability distributions they are practising in their quantitative risk analysis. However, from the literature, 'continuous-probability distribution' was identified as the most practised technique [8]. It also highlighted that 'triangular', 'beta', and 'uniform' distributions are the most common techniques in order to generate robust results in risk analysis. Although, these techniques are very mathematical and requires expert(s) in the field to not only do the analysis but also to interpret the results to help decision-makers. Therefore, it requires highly trained staff with a considerable level of investment in the organisations

## VIII. Conclusion

Risk assessment is a fundamental part of the decision-making process in the management of risks and uncertainties. It comprises the processes of identification, analysis, evaluation and control of risks. When operating efficiently, the process provides systematic knowledge coupled with detailed understanding of probable risks, their causes and predictive consequences. Failure in assessment of risks can be the source of inadequacy in the entire process of risk management, which consequently can lead to a failure in achieving organisational objectives. The choice of tools and techniques in risk assessment can influence the degree and scope of decision-making, and subsequently, the risk response strategy. Implementing appropriate tools and techniques determines the level of accuracy in the decision-making process. Thus, based on a mixed method questionnaire survey with public risk management organisations in the area of food, the environment and health and safety, the most practised risk identification tools were recognised as primary hazard analysis, brainstorming, hazard analysis and critical control point. The most frequently-used qualitative risk analysis tools were expert judgement and Risk Probability and Impact Assessment. The most practised quantitative techniques were explained as sensitivity analysis and data gathering and representation technique such as Probability Distributions.

The results of the study specified that the selection and implementation of tools and techniques in risk assessment is highly influenced by organisations' characteristics and their field of activities. However, this will be explored in more details in the main study.

The findings of this study provide knowledge for public risk regulation organisations and risk analysts on the range of available and currently in-use risk assessment tools and techniques for decision analysis. This also provides information about the strengths and limitations of the risk assessment tools and techniques which assist to understand the practical alternative of methodological approaches. The findings will further help to develop a framework for risk assessment and management processes for public risk regulation organisations.

## Acknowledgment

The Authors would like to express a special thanks and deepest appreciation for the support and funding received from the EPSRC and ESRC Centre for Doctoral Training on Quantification and Management of Risk & Uncertainty in Complex Systems & Environments, within the University of Liverpool and the industrial partners, the Health and Safety Executive (HSE) and the Food Standards Agency (FSA).

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