



Investigating the Measurement of Resilience Engineering for Improving Organisational Safety

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Abstract. This project investigates the measurement of resilience engineering. A growing body of peer-reviewed studies continues to be published on resilience engineering, demonstrates its recognition and importance to safety across a range of industrial contexts. However, little attention has focused on developing an understanding of how it has been conceptualized and measured. This is a significant gap which can limit its operationalization, benchmarking and evaluation for research and practice. This paper presents an integrative review project currently underway which seeks to address this gap. After completing a systematic search and selection strategy seventeen articles were selected for analysis. Initial findings suggest fifteen survey instruments have been used in these studies.

Keywords: Resilience engineering · Integrative review · Organisational safety PRISMA

1 Introduction

This paper is a work-in-progress and is part of a broader research project on advancing organisational health and safety through Resilience engineering (RE). RE was introduced as an approach for improving organisational safety following the Columbia space shuttle disaster [1]. The seminal work on the topic was published in 2006 [2] and included extended versions of papers presented and discussed at the first International Symposium on RE in 2004. Since then it has gained traction in a range of industries such as healthcare, nuclear power plants, petrochemical facilities, electricity distribution and railways [3, 4]. As such a growing body of knowledge on the topic is available. Despite this, progress on its adoption across contemporary high-risk industries such as construction, healthcare, manufacturing, and mining have been relatively slow. In part, this is due to the difficulty in operationalising RE [5]. There is no uniformly accepted definition of RE, and no common characteristics for evaluating RE

quantitatively [3]. Key proponents have argued for the need to focus on learning, responding, monitoring and anticipating [6]; while others have suggested behaviours [7], cognition [8], buffering, flexibility, margins and tolerance [9]; safety culture [1, 10]; safety trade-offs alongside production, quality and efficiency targets [9, 10], gap between work as imagined and work as performed [11, 12], or broader processes that assist organisations to achieve both safety and production targets [12]. This research seeks to address these gaps by investigating how RE has been measured in the published literature.

2 Method

An integrative review was adopted for this research. This method involves a structured approach and can be used to evaluate the strengths of evidence, identify gaps in the current research, build the bridge between related areas of published works, generate research question(s), identify theoretical or conceptual frameworks, and explore methods used [13]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [14] as adapted for a previous review [3] were used. Articles were selected based on a search of six electronic databases (CINAHL, Google Scholar, PsycINFO, PubMed, Scopus, and Social Sciences) using resilience engineering in the Titles and abstracts were searched and supplemented with additional ones from reference list of papers. Papers published in English between January 2003 and December 2019, which focussed on safety and described quantitative methods and approaches were included in the final selection. Key information relating to research aims, theory/model, research design, characteristics measured, and instruments used were extracted into an Excel sheet. The selected articles were critically appraised using a using an eight-item questionnaire adapted from the Critical Appraisal Skills Programme (CASP) [15] and the quality assessment tool of diverse study designs [16].

3 Results

The search across the six electronic databases and supplemented with hand searches generated 3884 articles from which a final set of seventeen was selected for analysis and synthesis. The backgrounds of these are summarized in Table 1. Fifteen surveys were reported across these studies. As previously indicated, the analysis and synthesis of this work are still in progress; however, some general statement can be made. Quantitative studies of RE did receive much attention until 2010, with the first two studies were published in 2013. Only four studies were supported with a theoretical framework such as with drift-towards failure [17] and organisational behaviour [18]. Two studies used an integrated RE theory [19, 20], while one safety culture [21].

Table 1. Background details of studies selected for final review

Context and Country	Purpose	Instrument
Gold Mining Australia	Introduced a theoretical framework for RE and a toolkit for investigating RE	Structured safety climate survey
Aviation Austria	Developed and validated an Inventory for assessing resilience through behaviour	Structured questionnaire surveys
Process industry Iran	Examined the validity of a survey method for measuring RE	Structured questionnaire surveys
Petrochemical plants Iran	Assessed factors affecting the resilient levels using Fuzzy cognitive maps	Experts' Views and Structured questionnaire survey
Petrochemical departments, Iran	Evaluated performance of Integrated RE through questionnaires and data envelopment analysis	Structured questionnaire survey
Public hospitals Iran	Designed a questionnaire to assess crisis management based on RE principles	Structured questionnaire survey
MSWM Companies Italy	Assessed Resilience in Municipal Solid Waste Management Companies	Structured questionnaire survey
Petrochemical plant Iran	Proposed framework to assess human resources productivity considering RE, motivational factors and health, safety, environment, and ergonomics	Structured questionnaire survey
Process industries Poland	Examined whether RE concept is related to the implementation of OSH management systems and safety performance	Structured questionnaire survey
Hospitals Iran	Present a new framework for assessing the crisis management based on RE principles	Structured questionnaire survey
Process industry Iran	Assessed RE factors based on system properties	Semi-structured interviews with MCQs, analysis of documents
Aluminium factory Iran	Evaluated Integrated Resilience Engineering (IRE) using mathematical programming	Structured questionnaire survey
Construction industry Canada	Developed and validated a Safety Climate Resilience Model	Structured questionnaire survey
Petrochemical Plants Iran	Designed a validated instrument to Measure Resilience Safety Culture	Structured questionnaire survey
Oil and gas industry Kuwait	Used resilient safety culture model to measure impact of remoteness and mental health	Structured questionnaire survey
Steel industry Iran	Quantified and determined priorities of RE dimensions	Structured questionnaire survey
Petrochemical Plants Iran	Evaluated impacts of RE on integrated health, safety, environment, and ergonomics management system	Structured questionnaire survey

3.1 General Characteristics of Studies and RE Measured

Eleven articles were published from Iran, with the remaining ones from Australia, Austria, Canada, Italy, Kuwait, and Poland. Industries from which these were published from included petrochemical plants, process industries, public hospitals, aviation, aluminum manufacturing, construction, gold mining, solid waste management and steel manufacturing. Fifteen (15) survey instruments were reported across these studies, suggesting this can be used for advancing quantitative evaluation of RE. As most of the published are from Iran, care needs to be taken when drawing from these for other countries. Similar care needs to be taken when proposing an instrument for the general industry because of the heterogeneity of the studies.

The number of RE characteristics measured in these studies differed considerably, with a minimum of three (3) and a maximum of thirteen (13). The most common characteristics measured included six of seven themes suggested by Wreathall [12]. Behaviours [7], buffering, flexibility, margins and tolerance [9] were included in two instruments; while cognition [7, 8], or the gap between work as imagined and work as performed [11, 12] were mentioned in one study but did not feature in any empirical investigations. What was not clearly spelt out, however, was what these characteristics specifically represented i.e. independent variables, mediating variables, or outcomes. This is something that needs to be investigated further.

4 Conclusion

This research is work-in-progress so any definitive conclusions regarding how RE has been measured in the literature cannot be made at this stage. However, the preliminary findings suggest that questionnaire surveys are the most common tools used for investigating RE quantitatively, so this can be used to conduct benchmarking studies in the field. Some key characteristics for measuring RE have been identified, but further analysis is required to specify what they represent. Findings from such analysis are useful in developing an appropriate theoretical framework and a supporting survey instrument for advancing quantitative RE studies. Future work will report on the development, pilot testing and validation of such surveys.

Acknowledgements. This research was supported through an internal University of Newcastle School of Health Science Strategic Pilot Grant Awarded to the first author in 2018.

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