KNOWLEDGE MANAGEMENT FOR SAFETY CULTURE - AN INTEGRATED FRAMEWORK FOR CONSTRUCTION INDUSTRY

Thesis

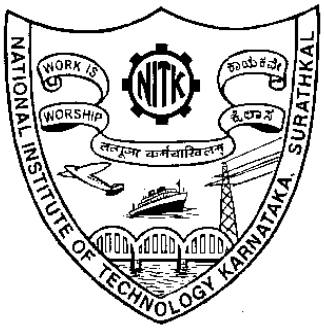
Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

DEEPAK M.D.

(158012CV15F15)



DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL, MANGALORE - 575025

DECEMBER, 2019

KNOWLEDGE MANAGEMENT FOR SAFETY CULTURE - AN INTEGRATED FRAMEWORK FOR CONSTRUCTION INDUSTRY

Thesis

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

DEEPAK M.D.

(158012CV15F15)

Under the guidance of

Dr. GANGADHAR MAHESH

Associate Professor

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA,
SURATHKAL, MANGALORE - 575025

DECEMBER, 2019

DECLARATION

I hereby declare that the Research Thesis entitled **"Knowledge Management for Safety Culture - An Integrated Framework for Construction Industry"** which is being submitted to National Institute of Technology Karnataka, Surathkal, in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in Civil Engineering, is a bonafide report of the research work carried out by me. The material contained in this Research Thesis has not been submitted to any University or Institution for the award of any degree.

DEEPAK M.D.
Register No.158012CV15F15
Department of Civil Engineering
NITK, Surathkal

Place: NITK, Surathkal

Date: 17th December, 2019

CERTIFICATE

This is to certify that the Research Thesis entitled "**Knowledge Management for Safety Culture - An Integrated Framework for Construction Industry**" submitted by Mr. DEEPAK M.D. (Register number: 158012CV15F15), as the record of the work carried out by him, is accepted as the Research Thesis submission in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy.

Dr. Gangadhar Mahesh
Research Guide
(Signature with date and seal)

Chairman - DRPC
(Signature with date and seal)

ACKNOWLEDGMENT

With deep sense of gratitude, I express my heartfelt thanks to my research supervisor Dr. Gangadhar Mahesh, Associate Professor, Department of Civil Engineering, NITK for his invaluable guidance, encouragement, and motivation throughout my research work. I am indebted to him for his wholehearted interest and keenness in every phase of research work and thesis preparation. His moral support, guidance, interactions, discussions and precious suggestions have greatly helped me to complete this research work. It has been my greatest opportunity and pleasure to work under him. His crucial comments have guided me to publish my research work in acclaimed International Journals. I would also like to convey my sincere thanks to my Research Progress Assessment Committee members, Dr. B.B. Das, Department of Civil Engineering and Dr. Savita Bhat, School of Management for providing valuable suggestions, comments and encouragement at various stages of this research work.

I would like to thank Prof. K. Swaminathan, Head of the Department of Civil Engineering and the former Heads Prof. K.N. Lokesh, Prof. D. Venkat Reddy, Prof. Varghese George for all the support throughout my stay. I am also thankful to all faculty and staff of Department of Civil Engineering for their help and support.

A special thanks to my family for their support throughout my journey. I am forever grateful to my father Sri. Dwarkinath, mother Smt. Rajalakshmi N.H. and my younger brother Mr. Karthik M.D. who provided me the best available education and encouraged in all my endeavors.

I lovingly acknowledge the moral support and help extended by my best friends and colleagues during this journey. Their informal support and encouragement have been very crucial. I am grateful to everybody who helped and encouraged me during this research work.

Date: 17/12/2019 **Deepak M.D.**
NITK, Surathkal

ABSTRACT

There has been a growing concern among researchers and practitioners on improving occupational health and safety in construction industry. In order to understand and improve occupational health and safety, many researchers and practitioners are utilizing the construct of safety culture. Considering the working nature of construction industry is mainly through projects that are transitional, knowledge and experience are generally lost when a project nears completion. Unfortunately, the transitory nature of work within the industry frequently hinders an organization's attempt to develop and maintain a good safety culture. Also, lack of knowledge management strategies in safety-related issues causes loss in the knowledge that is gained in the project. These missed opportunities for learning trigger reoccurrence of accidents and this accident repetition phenomenon can be mitigated by effective implementation of knowledge management strategies in construction projects. However, there is dearth of studies on knowledge management strategies to prevent reoccurrence of accidents and thereby improve safety culture in construction industry. Harnessing the power of knowledge management is important for minimizing accidents occurring at construction projects. Up until now, there has been no study that focuses on the influence of knowledge management as a key dimension to improve safety culture in construction industry. Moreover, from review of literature, knowledge dimension was found to be a neglected dimension in developing overall safety culture in construction industry.

Therefore, the aim of this study is to identify and assess key factors that affect knowledge-based safety culture in construction industry. The study first developed a conceptual framework with underlying factors that affect knowledge-based safety culture in construction industry. A questionnaire survey was formulated after identifying 69 influencing factors from a thorough literature review. In total, 210 valid responses were obtained from key stakeholders operating in Indian construction industry. Data collected from the survey responses were analyzed to assess the measurement scale by determining the reliability and validity of the survey instrument. The developed survey instrument provides a pragmatic approach for construction project managers to evaluate the effectiveness of their safety management practices and identify the effort needed for improvement of safety.

Results suggest that the survey instrument appears to be a reliable, valid and sensitive instrument that will contribute in examining the effect of key factors that influence the importance of knowledge dimension towards developing safety culture in the construction industry. Further, the causal relationship between knowledge-based safety culture dimensions is determined by conducting Partial Least Square Structural Equation Modelling (PLS-SEM). Results indicate that all safety culture constructs including the neglected knowledge dimension are effective in explaining the overall safety culture of construction industry. Understanding the relationship among the key factors that impact knowledge-based safety culture is important for assessing cultural aspects of the work system.

For continuous monitoring and reviewing safety culture in any organization, an assessment framework is a prerequisite. To achieve this, results of the questionnaire survey are used to develop an assessment framework using critical knowledge-based safety culture factors. Different case scenarios were considered to validate the assessment framework. Through this analytical framework, safety culture scores can be computed and the assessed scores can facilitate benchmarking. This will help in determining the strengths and weaknesses of safety management practices and thereby encourage organizations to improve in these areas. The outcome of this research could be utilized to configure targeted safety practices and enhance overall safety performance of construction industry. Also, this research can contribute to the promotion of safety theory in Indian construction industry and provide practical implications for construction enterprises when they engage in improving safety conditions in their organizations.

Keywords: safety; safety culture; knowledge; knowledge management; construction industry

TABLE OF CONTENTS

DECLARATION

CERTIFICATE

ACKNOWLEDGMENT

ABSTRACT

TABLE OF CONTENTS i

LIST OF TABLES vi

LIST OF FIGURES vii

NOMENCLATURE viii

1 INTRODUCTION 1

1.1 BACKGROUND 1

1.2 WORKPLACE SAFETY IN INDIAN SCENARIO 2

1.3 ACCIDENT ANALYSIS AND SAFETY CULTURE REQUIREMENTS 3

1.4 RESEARCH AIM AND OBJECTIVES 6

1.5 SCOPE AND SIGNIFICANCE OF THE STUDY 7

1.6 OUTLINE OF THE THESIS 8

2 LITERATURE REVIEW 11

2.1 INTRODUCTION 11

2.2 BACKGROUND 11

2.3 RECENT TRENDS AND ADVANCES IN SAFETY CULTURE 13

2.3.1 Term analysis of safety culture research areas 15

2.3.2 Descriptive analysis of safety culture research 16

2.4 SYSTEMATIC LITERATURE REVIEW ON SAFETY CULTURE RESEARCH 19

2.4.1 Defining safety culture in organizations 19

2.4.2 Factors affecting safety culture in organizations 21

2.4.3 Assessment tools for measuring safety culture in organizations 26

2.5 STUDY OF SAFETY CULTURE MODELS AND ITS ADVANCEMENTS 29

2.5.1 Safety culture models 29

2.5.1.1 Bandura’s model of reciprocal determinism 30

2.5.1.2 Cooper’s reciprocal safety culture model 31

2.5.1.3 Järvis and Tint reciprocal model of safety culture 32
2.5.2 Construction safety culture 35
2.6 SAFETY CULTURE AND KNOWLEDGE MANAGEMENT ASPECTS 37
2.6.1 Knowledge management in organizations 37
2.6.2 Role of safety knowledge in organizations 38
2.6.3 Need for integration of knowledge management in occupational health and safety 39
2.7 SIGNIFICANCE OF KNOWLEDGE MANAGEMENT IN SAFETY MANAGEMENT 40
2.8 SIGNIFICANCE OF KNOWLEDGE MANAGEMENT IN SAFETY CULTURE STUDIES 43
2.9 FACTORS AFFECTING KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION INDUSTRY 44
2.9.1 Implications from literature review 47
2.9.2 Purpose of the proposed model 47
2.10 RESEARCH HYPOTHESIS 48
2.11 CHAPTER SUMMARY 52
3 RESEARCH METHODOLOGY 53
3.1 INTRODUCTION 53
3.2 REVIEW OF RESEARCH METHODS 54
3.2.1 Research approaches 54
3.2.2 Sampling techniques and sample design 56
3.3 SELECTING APPROPRIATE METHODS FOR THIS RESEARCH 57
3.3.1 Literature review (Systematic Literature Review) 57
3.3.1.1 Literature search 58
3.3.1.2 Term analysis 59
3.3.1.3 Literature selection 59
3.3.1.4 Literature coding 59
3.3.1.5 Systematic literature review 59
3.3.2 Questionnaire survey 60
3.3.3 Case studies and interviews 63
3.4 METHODS OF DATA ANALYSIS 64
3.5 ETHICAL CONSIDERATIONS 67

3.6 RESEARCH METHODS IN RELATION TO OBJECTIVES 68
3.7 CHAPTER SUMMARY 69
4 QUESTIONNAIRE INSTRUMENT DESIGN 71
4.1 SURVEY DESIGN AND ADMINISTRATION 71
4.2 PILOT STUDY 71
4.2.1 Purpose of pilot study 71
4.2.2 Pilot study administration 72
4.2.3 Pilot study responses 72
4.2.4 Impact of pilot study responses on main survey 72
4.3 MAIN STUDY 73
4.3.1 Data collection for main study 74
4.3.2 Sampling method 76
4.4 DATA COLLECTION FOR MAIN STUDY 77
4.5 CHAPTER SUMMARY 80
5 INSTRUMENT FOR ASSESSING KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION ORGANIZATIONS 81
5.1 INTRODUCTION 81
5.2 RELIABILITY AND VALIDITY OF THE MEASUREMENT SCALE 81
5.3 RELIABILITY TEST OF THE MEASUREMENT SCALE 82
5.4 VALIDITY TEST OF THE MEASUREMENT SCALE 83
5.4.1 Exploratory factor analysis 83
5.4.2 Multiple Analysis of Variance (MANOVA) 90
5.5 CAUSAL RELATIONSHIP OF KNOWLEDGE-BASED SAFETY CULTURE DIMENSIONS 92
5.5.1 Partial least square (PLS-SEM Approach) 92
5.5.2 Assessment of measurement model 94
5.5.3 Assessment of structural model 97
5.6 DISCUSSION 101
5.6.1 Development of knowledge-based safety culture measurement scale 101
5.6.2 Causal relationship between knowledge-based safety culture constructs and overall safety culture 103
5.7 CHAPTER SUMMARY 107

6 DEVELOPMENT OF ASSESSMENT FRAMEWORK FOR KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION INDUSTRY **109**

6.1 INTRODUCTION 109

6.2 QUANTITATIVE FRAMEWORK 109

6.2.1 Development of quantitative framework 110

6.2.2 Importance of main factors 111

6.2.3 Importance of sub-factors 112

6.3 SAFETY CULTURE ASSESSMENT FRAMEWORK 114

6.4 EVALUATION OF ASSESSMENT FRAMEWORK IN CONSTRUCTION ORGANIZATIONS 115

6.5 INTERVIEW ANALYSIS 119

6.5.1 Methodological issues 120

6.5.2 Sampling frame 120

6.5.3 Data analysis 121

6.5.3.1 Impact of certification credentials on safety culture 122

6.5.3.2 Important aspects of cultivating good safety culture in organizations 124

6.5.3.3 Importance of knowledge management strategies to improve safety culture 125

6.5.3.4 Barriers to adopt or implement knowledge management strategies for developing safety culture 127

6.5.4 Summary of interview analysis 129

6.6 IMPROVEMENT FRAMEWORK FOR OVERALL SAFETY CULTURE 129

6.7 CHAPTER SUMMARY 133

7 CONCLUSIONS AND RECOMMENDATIONS **135**

7.1 INTRODUCTION 135

7.2 REVIEW OF RESEARCH OBJECTIVES AND MAJOR FINDINGS 135

7.3 THEORETICAL IMPLICATIONS 138

7.4 PRACTICAL IMPLICATIONS 139

7.5 LIMITATIONS OF THE STUDY 141

7.6 FUTURE RESEARCH DIRECTIONS AND RECOMMENDATIONS 141

7.7 CHAPTER SUMMARY 144

REFERENCES 145
Annexure-A 173
Annexure-B 180
Annexure-C 183
Annexure-D 195
LIST OF CONFERENCES AND PUBLICATIONS 197
BIO-DATA 198

LIST OF FIGURES

Figure no.	Figure description	Page no.
1.1	Comparison of the level of working accidents among different sectors	4
1.2	Level of working accidents based on location	5
2.1	Term analysis of safety culture articles	16
2.2	Article distribution by publications	17
2.3	Article distribution by year of publication	18
2.4	Cumulative article distribution by year of publication	18
2.5	Country/region-wise distribution	19
2.6	Distribution of factors affecting safety culture	26
2.7	Bandura's model of reciprocal determinism	30
2.8	Reciprocal safety culture model	32
2.9	Reciprocal model of safety culture	33
2.10	Need for knowledge-based safety culture (Gaureanu et al., 2016)	40
2.11	Model showing interrelationship between safety culture dimensions	42
2.12	Model showing interrelationship between types of knowledge management	42
2.13	The theoretical model	49
2.14	Proposed conceptual framework of safety culture	50
2.15	Conceptual framework of overall safety culture with influencing factors	51
3.1	Operational research model	53
3.2	Systematic literature review flowchart	58
4.1	Demographic profile of survey respondents	79
5.1	Hypothesized detailed relationship model	94
5.2	Initial path model	98
5.3	Final path model	100
6.1	Construction knowledge-based safety culture framework	110
6.2	Case comparisons of safety culture score in organizations	118
6.3	Improvement framework of overall safety culture	132

LIST OF TABLES

Table no.	Table description	Page no.
2.1	Safety culture definitions	20
2.2	List of factors influencing safety culture dimensions	23
2.3	Safety culture assessment tools	27
2.4	Description of prominent safety culture models	34
2.5	Significant link between knowledge management types and safety culture elements	41
2.6	Factors affecting knowledge-based safety culture in construction industry	45
4.1	Number of safety culture factors	74
4.2	List of chapters in CREDAI-Karnataka region	75
4.3	Demographics of the study sample	78
5.1	Descriptive statistics of knowledge-based safety culture constructs	83
5.2	KMO and Bartlett's Test	84
5.3	Factor structure of knowledge-based safety culture constructs	85
5.4	Discriminant validity of knowledge-based safety culture constructs	91
5.5	Measurement model evaluation	96
5.6	Correlation of latent variables and AVE values	97
5.7	Structural properties of the constructs	99
6.1	Summary of mean score of main factors of safety culture	111
6.2	Summary of mean score of sub-factors of safety culture	113
6.3	Knowledge-based safety culture assessment framework	116
6.4	Background of the interviewees	121

NOMENCLATURE

CFA	Confirmatory Factor Analysis
CIRC	Construction Industry Review Committee
CIDC	Construction Industry Council of India
CREDAI	Confederation of Real Estate Developers Association of India
EFA	Exploratory Factor Analysis
GDP	Gross Domestic Product
GoF	Goodness-of-Fit
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ILO	International Labor Organization
KBS	Knowledge-Based System
KM	Knowledge Management
MANOVA	Multiple Analysis of Variance
OH&S	Organization Health and Safety
OHSAS	Occupational Health and Safety Assessment Series
OSHA-USA	Occupational Safety and Health Assessment-United States of America
OSHE	Organization Safety Health and Ergonomics
PLS-SEM	Partial Least Square – Structural Equation Modelling
SC	Safety Culture
SCI	Safety Culture Index
SEM	Structural Equation Model
SK	Safety Knowledge
SPSS	Statistical Package for the Social Science

CHAPTER 1

INTRODUCTION

This chapter introduces the background of the research study and highlights the requirement of safety culture in construction organizations, particularly in Indian construction industry. It features the research question formulated for the study, states the aim statement and defines the research objectives of the study. In addition, it describes the scope and significance of the study and outlines the structure of the thesis.

1.1 BACKGROUND

Most developed countries have implemented various safety, health and environmental management systems to meet the challenges of construction industry, especially with respect to safety, such as higher accident rates, hazardous situations, complex nature of work and uncontrolled working conditions (Choudhry et al., 2008). Most of these developed countries perform better than most developing countries in terms of occupational safety management (Lin et al., 2008) and consistently strive to minimize the rate of accidents in construction industry. However, major differences in terms of health and safety between developed and developing countries include the non-existence of safety legislation and its ineffective enforcement, poor hazard assessment techniques, and absence of safety awareness campaigns (Azhar and Choudhry, 2016; Choudhry and Zahoor, 2016). Such a deteriorating situation not only results in severe accidents on worksites but also results in absence of workers from job sites with lower morale of workers, construction delays, and conflicts between the stakeholders (Farooqui et al., 2008). The benefits of improving occupational safety is to increase efficiency, competitiveness, productivity, and profitability by reducing injuries, incidents, accidents and illness rates (Chan et al., 2008; Hon et al., 2012, 2014).

In complex, dynamic and critical safety construction processes, it has been argued that a purely formal approach to ensure safety is not sufficient to build a safe working environment. This implies that a cultural approach should be used as a supplement to revisit the information from previous projects in addition to traditional safety

management practices. The culture of an organization is similar to an individual's identity and determines their beliefs and values and directs their behaviour. In this regard, the concept of safety culture has been used to explain the differences in terms of differing safety performance, although the risks, technologies, rules and regulations are similar (Lingard and Yesilyurt, 2003; Trethewy, 2003). Organizations with a strong safety culture generally operate according to key assumptions supporting safety values and priorities (Hale, 2000). Also, studies on safety culture involve understanding and utilizing cultural phenomena in the project network and engage when signs of safety culture deteriorate. Ultimately, in the construction work process, a systematic approach to safety culture helps to ensure that all operations in this process are carried out in compliance with standards, quality and safety objectives during all construction lifecycle phases.

1.2 WORKPLACE SAFETY IN INDIAN SCENARIO

In India, the construction industry is the second-largest employer as well as the second largest economic sector after agriculture. Its contribution to Gross Domestic Product (GDP) is more than 5% and nearly accounts for 78% of gross capital formation (IS-2014). About 16% of workforce in India depends for its livelihood on construction sector. Construction sector in India has over 35 million workers and in 2014-2015, it produced assets worth Rs. 200 billion and contributed to about 65% of the overall infrastructure investment being made in this sector (Dixit et al., 2018). Building investment comprises of about 11% of India's GDP. Construction industry's market size for 12th Five Year Plan (2012-17) period has shown that the industry aggregate output is likely to be 52.31 lakh crores in this period (IS-2014).

The Indian construction industry is currently very large and complex with a large workforce and involves the latest technology. Apart from the large and complex nature, the rapid development has brought forth safety and health issues in the construction industry. The construction sector in India has the most vulnerable segment of the unorganized labour force which accounts for 7.5% of the world labour force and contributes to 16.4% of global fatal accidents (Kulkarni, 2007). A recent study conducted by ILO (International Labour Organization), shows that 165 out of 1,000

workers get injured at the workplace and points out that India has the highest accident rates among construction workers in the world.

At construction sites, significant number of employees are exposed to the risk of accidents and occupational health problems. Although several Indian regulations deal with the working conditions of construction workers, their effectiveness is yet to be felt. It is a fact that despite all efforts made by some of the elite construction firms, and safety enforcement to reduce accidents and incidents in job sites, they are growing and, in many instances, a lack of awareness has become evident. Therefore, more focus should be given to enhance awareness of safety-related issues in the construction workers. Above all, everyone involved in the construction activities should be responsible for detecting and removing potential risks from construction job sites. Furthermore, focus on safety cultural aspects has been shown to contribute to improve health and safety performance among individuals of construction industry (Loosemore et al., 2019).

1.3 ACCIDENT ANALYSIS AND SAFETY CULTURE REQUIREMENTS

Safety at the workplace of construction projects is essential and requires more attention towards minimizing accident rates. Accidents and fatalities continue to haunt safety, health and well-being of construction personnel (Lin et al., 2008; Gürcanli and Müngen, 2013; Khosravi et al., 2014), especially in developing countries. In this regard, many policies and strategies are being implemented for improving safety performance in construction industries worldwide. However, problems concerning awareness of safety risks, procedures and practices still exist in the industry, which indicate shortfalls in diffusion of safety-related knowledge in construction industry. These problems are intensified by the nature of work, the people engaged in work and the organization's management system. It has been noted that poor safety culture is one of the key attributes that causes injuries and fatalities in the construction sector worldwide (Choudhry et al., 2007). An effort to measure safety culture at work is therefore extremely important to create a safe working condition and ultimately to reduce construction work accidents (Machfudiyanto et al., 2017). The impact caused by work-related accidents is fairly large and along with the reduction in fatalities and a declining

standard of living for employees, these work-related accidents in construction projects result in project delays, increase product costs, health expenses, and other negative effects (Chen et al., 2008).

Construction sector is considered to have the highest rate of injuries among all sectors and is accountable for the most severe injuries (Høyland et al., 2018; Kim et al., 2019). This sector has at least 108,000 workers killed every year worldwide, representing about 30% of fatal accidents at work (Gürcanli and Müngen, 2013). Recent data (Figure 1.1) shows that, the level of working accidents (injury and illness rate) in construction industry accounts for 32% (Machfudiyanto et al., 2017), which is much greater than the average of other industries (Hallowell, 2011).

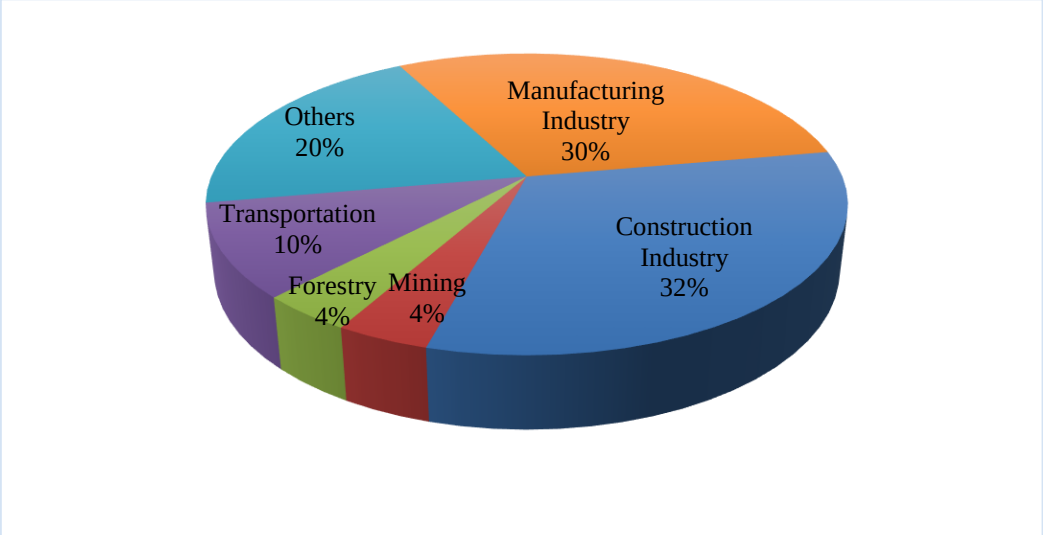


Figure 1.1 Comparison of the level of working accidents among different sectors

Furthermore, in consideration of working accidents occurring to the workforce involved within the construction sector (Figure 1.2), about 70% of the accidents happen inside the company itself, 20% considered are traffic accidents and the remaining occur outside the company (Machfudiyanto et al., 2017).

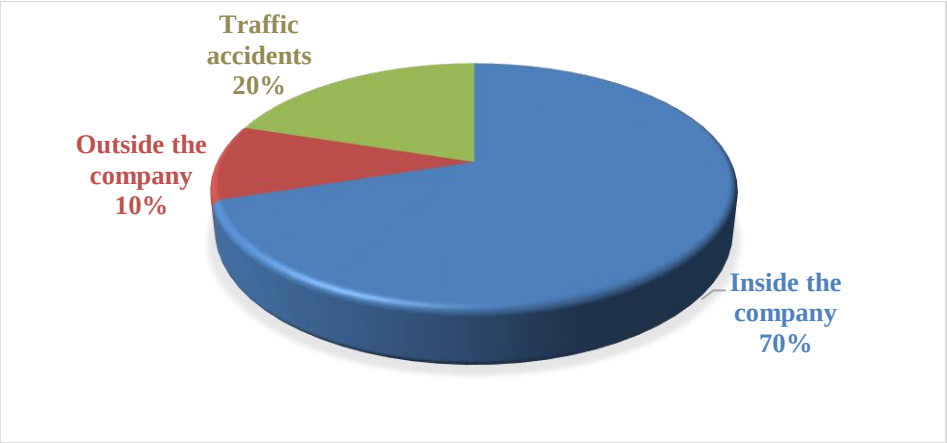


Figure 1.2 Level of working accidents based on location

This data shows that safety culture process seems far from what several stakeholders anticipate and it implicitly signifies the importance of safety culture in construction industry. The increase in safety culture can be understood in favour of organizations in minimizing incidents, fixing the reputation of the industry and increasing safety at work (Kartam et al., 2000).

Generally, in construction projects, there is constant change in nature, place, and workers involved. This often leads to progress in project sites but still inevitably causes accidents and fatalities without learning from previous mistakes. This can be overlooked if there is a suitable mechanism to "re-invent the wheel" to be able to prevent accidents to reoccur in the near future. This leads to effective implementation of knowledge management strategies to enforce safety rules and regulations and develop a positive safety culture to act upon construction projects. These transformations also have a serious influence on the assessment of safety process in the construction industry.

The implementation of knowledge management strategies for accumulating, storing, sharing and transferring knowledge related to safety is identified as an approach that could lead to continual improvement in worker safety and development of broader workplace safety culture in the construction industry (Podgórski, 2010; Järvis et al., 2014). Analogous with safety, effective change towards identifying, capturing, storing

and transferring of safety knowledge plays a prominent role in construction organizations (Hallowell, 2011).

1.4 RESEARCH AIM AND OBJECTIVES

In view of the issues mentioned earlier, the aim of this research work is to identify factors required for the development of knowledge dimension to improve safety culture of construction industry. As the development of safety culture is intended to improve safety performance, it requires understanding of the influencing factors for the development of safety knowledge.

The research is from an academic perspective to provide insight into the relationships between safety culture dimensions and their interaction with outcome measures such as behaviour, rate of accidents or injuries, etc. The ultimate focus of developing safety culture is to minimize accident rates in the construction projects. On the other hand, empirical examinations of how individual's perception towards understanding the safety interactions with overall safety culture of the organization have not yet been conducted. This indicates a need to conduct a study to examine the organization's safety culture. Hence the research question would be defined as:

Research question: How knowledge related to safety should be managed as an antecedent of safety culture in the construction industry?

Aim Statement: To integrate knowledge management dimension into safety management practices for improving safety culture in the construction industry.

The purpose of this research is to enhance safety performance of construction industry and for achieving the same, the specific objectives of the present study are as follows:

- Identification and collation of safety knowledge elements that generally affect safety culture.
- To assess the relevance of identified elements for the construction industry and evaluate the degree of the interdependency of the identified elements.
- To develop an overall safety culture framework for the construction industry by incorporating knowledge management strategies.

1.5 SCOPE AND SIGNIFICANCE OF THE STUDY

Studies related to safety culture have attracted many researchers in developed countries, yet not much has been done in developing countries. Also, intervention studies in safety literature are clearly lacking in a cultural shift (DeJoy, 2005; Hale et al., 2010). This could be due to the general underdevelopment of theoretical frameworks for safety culture and a weak or even non-existent association to research on organizational culture (Choudhry et al., 2007; Clarke, 2000). For instance, there is no widely accepted safety culture model or consensus on how an organization's safety culture can be defined or described. Consequently, the concept of safety culture is therefore elusive and not readily expressed in attempts for reformation. One way of addressing this is to view safety culture as an integrated part of the more general concept of organizational culture. In general, safety culture can be understood as the elements or parts of the organizational culture that influence attitudes and behaviors that have an effect on the organization's level of safety (Hale, 2000). In safety culture studies, researchers have not consistently included concepts of knowledge management despite conceptual and empirical justifications. Therefore, the scope of the present work is to explore the prospect of utilizing knowledge management strategies in organizational health and safety management system of construction industry. This study primarily focuses on the examination of safety culture through addition of knowledge dimension that aims towards its improvement among construction organizations.

The scope of the work also underlines the importance of safety culture in the construction industry. An organization's safety culture is also a key determinant of good safety performance (Booth et al., 1995; Gherardi and Nicolini, 2002; Sorensen, 2002). Hence, in this adaptation, each of safety culture’s contributary factors can be directly measured in its own right and, in addition, safety culture can be quantified in a meaningful manner at different organizational levels, which have been very difficult to measure or quantify. Therefore, it is imperative to look in a broader perspective to direct theoretical development of safety culture with organizational practices that seek to reduce accidents and injuries and save lives. Moreover, limited attention is given to generalization of the developed safety culture measurement scales, especially in developing countries. The present study addresses this shortcoming by developing and

testing a 69-factor knowledge-based safety culture survey instrument in the Indian context.

The study not only identifies contributary knowledge-based safety culture factors for construction organizations but also strengthens the existing body of knowledge by revealing the deviations in these factors underlying each safety culture dimension in terms of its importance. The potential unveiling of novel inclusion of knowledge dimension in existing safety culture models would confirm the inevitability of integrating these dimensions while designing a safety culture measuring instrument. Furthermore, identification of causal influence of knowledge-based safety culture factors towards improving overall safety culture is expected to guide construction stakeholders in prioritizing their efforts towards safety enhancement.

Ultimately, an assessment framework is formulated to measure overall safety culture that encloses existing safety culture dimensions with addition of the neglected knowledge management dimension in the overall framework. This framework is anticipated to guide construction organizations to measure, monitor and enhance cultural aspects of working system with regard to safety in construction organizations. Lastly, an improvement framework is presented that helps to develop an interactive learning environment and provides effective safety training and learning opportunities to aid knowledge management strategies for improving safety culture in construction organizations.

1.6 OUTLINE OF THE THESIS

The thesis consists of 6 chapters. Overview of these chapters are as follows:

Chapter 1 provides an introduction to the study. This chapter highlights the research background, defines the research aim and objectives, and highlights the scope, significance, and value of the study.

Chapter 2 presents a comprehensive review of literature to provide a foundation for the research objectives. This chapter majorly covers a systematic review of literature pertaining to safety culture in construction industry. Then, it explains the importance of knowledge management strategies and their influence on safety management practices

in construction industry. Based on the gaps identified from review of literature, a detailed list of contributary knowledge-based safety culture factors were identified, and based on this, a conceptual model is proposed and research hypothesis for the study are developed.

Chapter 3 introduces and explains research methodology employed to fulfill the objectives of the study. Both quantitative and qualitative research methods that were considered relevant to this study are discussed in detail.

Chapter 4 outlines the design of questionnaire survey instrument that is required to assess knowledge-based safety culture in construction organizations and data collection technique employed for the study.

Chapter 5 presents the results of analysis and discussions pertaining to assessing knowledge-based safety culture in construction organizations through the measuring instrument. Survey responses that were collected for this study were analyzed to assess the measuring instrument and the contributary factors. Next, the causal relationship of knowledge-based safety culture dimensions was evaluated to examine their influence and impact on overall safety culture of construction industry. Also, this chapter highlights the significance of the development of an effective measurement tool to measure knowledge-based safety cultural aspects in construction organizations.

Chapter 6 presents a detailed methodology to develop an assessment framework based on the importance of the factors that contributed in shaping positive safety culture in construction organizations. This assessment framework was tested in different case scenarios to verify the importance of these factors. In order to evaluate the differences arising based on the potential scores of case scenarios, semi-structured interviews were undertaken. Findings from interview analysis are used to support the results of the survey and provide insight as to how knowledge-based safety culture was perceived in different case scenarios of construction organizations and as a means of triangulating the scores obtained from assessment framework. Summary of main findings based on these analyses suggested formulating an improvement framework to improve the overall safety culture among construction organizations.

Chapter 7 concludes by providing a summary of research findings and their implications to the existing body of knowledge within the construction industry. Also, this chapter highlights limitations of the research work and suggests scope for further studies.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the literature and sets foundation for attaining the objectives of the study. It covers a brief overview of safety culture and examines recent trends and advances in safety culture research through a systematic literature review. This majorly covers; the conception of safety culture, defining safety culture in organizations, contributory factors affecting safety culture, and assessment tools to measure safety culture in organizations. Further discussion pertains to the need for safety culture models and its advancements in construction organizations. This chapter also provides a detailed overview of the proposed conceptual model of overall safety culture and highlights the research hypothesis formulated for the study.

2.2 BACKGROUND

The term safety culture was first introduced by IAEA (International Atomic Energy Agency) (IAEA, 1986) and was defined as 'the assembly of characteristics and attitudes of individuals in organizations which establishes a priority regarding nuclear plant safety issues' (IAEA, 1991). The most cited definition relevant to construction industry is "safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to the style and proficiency of an organization's safety management system" (Flin et al., 2000). The concept of safety culture has been studied in the last 25 years by many researchers from different academic fields. In these studies, two distinct perspectives were identified; the engineering approach, which focuses mainly on the formal aspects that influence business safety (procedures, managerial systems, controls, and policies), and a psychological approach, which focuses on the perceptions, competencies, and attitudes of employees (Antonsen, 2009).

Past studies have indicated that when there is a shortcoming of understanding the value of safety and its priority within the workplace, and then unsafe behaviours were likely

to result in an accident. Organizations are now focusing on those relevant human factors that contribute to workplace safety (Clarke, 2013; Jiang and Probost, 2016; Mullen et al., 2017). Studies have demonstrated that even employees with technical knowledge of working safety sometimes show behaviors that are inconsistent with the safety standards required by companies (Henroid and Sneed, 2004; Sneed and Henroid, 2007). In this regard, safety culture has become critically important within the construction site environment for the safety of employees involved in the work (Choudhry et al., 2007). Even though the concept of safety culture is relatively new within the construction industry, it is gaining popularity because it utilizes proactive measures, upstream, or leading indicators such as measurement of safety climate (Flin et al., 2000; Mohamed, 2002). Safety climate is defined as "the perceptions of employees about safety in their work area" (Zohar, 1980). The concept of safety climate is essential as it addresses organization culture (Guldenmund, 2000) and considers employee's attitudes and perceptions towards safety. The safety climate approach relies and focuses on current safety activities to establish the success of the safety management system rather than relying and focusing on system failures (Cooper et al., 2004).

Safety culture is crucial to construction industry (Fang et al., 2006); in particular, given the lack of reputation for the safety records of construction industry (Mohamed, 2002). CIRC (2001) in Hong Kong proposed several strategies for construction industry excellence, with one of their key strategies being promoting safety culture at all levels in the industry. Hinze (1997) defines safety culture as something that starts at the top management, and if it is genuine, it is felt at workers' level. However, Choudhry (2002) revealed that the desired improvement of safety is critical to the success of both management involvement and employees support. Arboleda et al., (2004) established means of examining and categorizing safety culture by establishing a distinction between management attitudes and workers behaviour, which is viewed separately but has a significant relationship. Langford et al., (2000) claimed that willingness of employees to cooperate and improve safety performance can only be felt if there is commitment and involvement from top management who care about personal safety of employees.

Studies have been done on working safety culture in manufacturing industry (Cox et al., 1998), yet the concept is relatively new in the construction industry (Machfudiyanto et al., 2017). However, there are many recent research efforts that focus on safety culture in construction industry. For example, Hallowell (2011) investigated the potential to include factors like individual perception and psychology, attitude towards work, management, and organizational factors. Careful understanding of safety culture shows how safety culture improves industry standards to allocate resources and improve occupational health and safety performance (Ho et al., 2004).

Altogether, safety culture must be established as an integral part of organization's work culture. It should also be considered as one of the basic components just as profit-making philosophy of the management. The ultimate aim should be to provide a safe and conducive working environment that can promote health and well-being to the employees and thus able to generate the feeling of trust and loyalty among the employees.

2.3 RECENT TRENDS AND ADVANCES IN SAFETY CULTURE RESEARCH

For the last two decades, there has been a rising concern among researchers and practitioners towards improving occupational health and safety in construction industry. To overcome this issue, organizations are encouraged to improve safety culture which has been a vital subject of research worldwide as it plays a major role in avoiding workplace accidents. However, there exists diversity in topics of safety culture studies related to construction industry making it difficult to have a clear and comprehensive overview in this field. Towards addressing this issue, a comprehensive review of previous studies was undertaken to provide an overview of trends and issues in research on safety culture in construction industry.

Recent studies in construction industry have focused on measuring, sustaining and improving safety culture (Choudhry et al., 2007; Gadd and Collins, 2002; Latief et al., 2017). Assessing safety culture is reflected as a proactive method of safety performance (Cesarini et al., 2013; Haslam et al., 2016). Hence, most of the construction projects aim to minimize injuries and strive to achieve zero incidents, which can only be reached by thriving towards a positive safety culture within the construction industry (Choudhry

et al., 2007). Also, frequency of occurrence and severity of the nature of most accidents at construction sites makes it imperative to understand safety culture in the industry.

From various literature, some of the predominant issues addressing safety culture in construction industry are:

(1) Transience of the industry - Degree of transience has to be considered for addressing safety culture because there is a constant change in the nature of construction activities. In this regard, the development of shared perceptions gets hampered as construction industry involves employment with high turnover rate (Schwatka et al., 2016).

(2) Subcontracting - Most of the construction projects involve multiple subcontractors to complete the associated work. The main contractor and subcontractor become involved within the project with their own safety rules, regulations, policies, procedures, values and standards (Lingard et al., 2010). This leads to ambiguity towards a unified safety culture for construction workplace.

(3) Work organization - Antonsen's (2009) study of safety culture provides insights about isolation of group and ways in which safety is improvised. Indeed, most construction projects lack structured and organized system for flow of work. This arises for a potential requirement of work-group level, project level, and organizational level to clarify the ways to improve safety culture (Lingard et al., 2014).

(4) Induction/acculturation process - Ethnographic studies (Antonsen, 2009; Gherardi et al., 1998) have provided a strong emphasis for understanding the influence of safety culture perception into industry practices through induction and acculturation process. This process enables positive safety culture development and in turn reduced number of accidents (Hartley and Cheyne, 2012).

These aforementioned issues shape the conception of safety culture as quite complex. Although, the concept is challenging content-wise; and multi-dimensional, it is a cross-disciplinary study area (van Nunen et al., 2017). These issues mainly address safety culture in an organization and need utmost attention for facilitating positive safety culture formation to reduce accidents, hazards, and risks in the working level of the

industry. Also, in addressing these adverse effects or issues, organizations need to encourage safety culture practices for creating a positive working environment within the organization. Dealing with issues of safety culture research is moderately new in terms of academic studies. This conception of safety culture began in reaction to Chernobyl disaster which occurred in 1986 (EU-OSHA, 2011), and with time, there is rapid increase in studies on safety culture. In spite of utmost considerations, accidents and incidents still remain a concern in the industry. The notion of improving safety culture at the workplace is believed to act as accident prevention system (Gabryelewicz et al., 2015). This has led to constant growth in number of articles on this topic, thus making it challenging to attain a detailed overview of this topic.

The number of articles present on a particular research area or field is usually enormous, which makes it difficult for researchers and practitioners to get an overview of specific information (Rodrigues et al., 2014; Zhou et al., 2015). This can quantitatively be analyzed based on information pertaining to publication history, features and progress of scientific outcomes within a particular research area or field (Jia et al., 2014; Li and Hale, 2016). However, there exists diversity in topics of safety culture studies related to construction industry which makes it challenging to have a clear and comprehensive overview in this field. In an effort to address this knowledge gap, a comprehensive review of articles related to recent trends and issues in understanding and promoting safety culture of construction industry is carried out and for achieving the same data is collected from various safety culture research studies and is analyzed. Detailed methodology adopted in this case is presented in next chapter (section 3.2).

2.3.1 Term analysis of safety culture research areas

Literature-search on the topic of 'safety culture' based on selection criteria yielded 140 articles. These articles are further analyzed to offer insight into key topics and trends of safety culture research domain. This has been carried out through 'Term Analysis'. Results of Term analysis are shown in Figure 2.1. From the analysis, the magnitude of the circles denotes the occurrence of a term. Distance between the terms offers information on their relatedness. Relatedness of the terms is signified based on the occurrence of the terms. Different colors distinguish one another from belonging to

different groups. Most common keywords obtained are; safety culture, accident prevention, human, safety, safety climate, safety performance, surveys, occupational safety, safety engineering and construction safety.

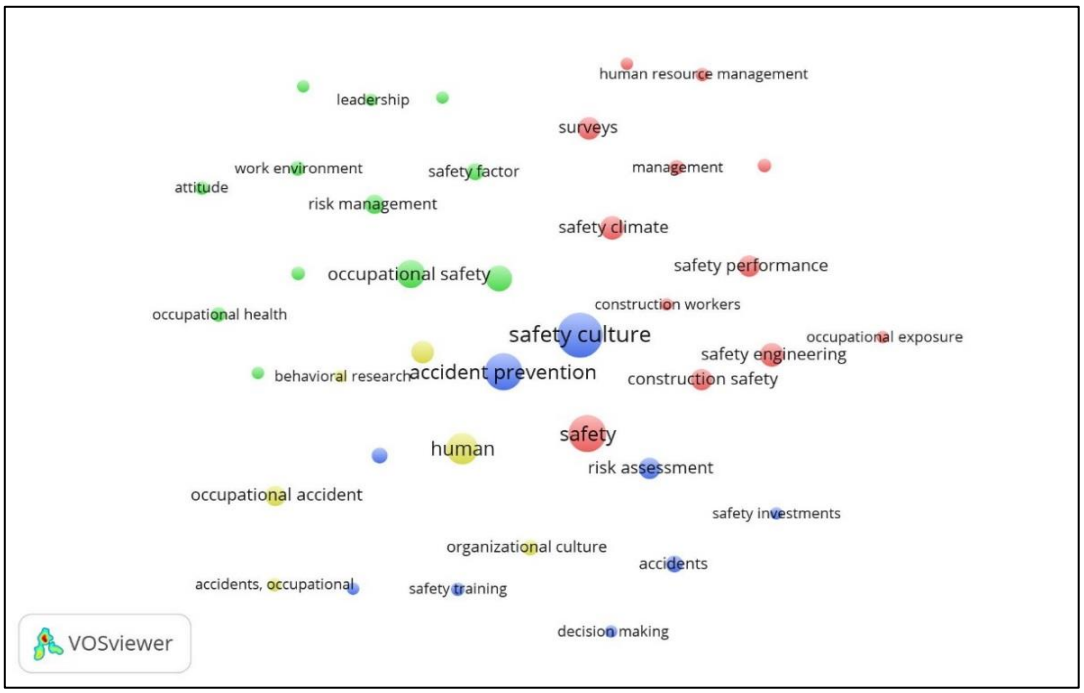


Figure 2.1 Term analysis of safety culture articles

2.3.2 Descriptive analysis of safety culture research

Results that are attained from the data of codified articles are presented in this section. Descriptive analysis is conducted to have an overview of current status of safety culture studies in construction industry. Recent trends in safety culture research of construction industry are analyzed by presenting the distribution of safety culture articles based on; i) publication, ii) year of publication, and iii) country/region-specific.

The amount of scientific articles published is an essential indicator to quantify the trend in a particular research area or field (van Nunen et al., 2017). A total of 140 articles were obtained from literature-search and was further scrutinized based on criteria that focus on relevant field of study. As a result, 51 articles were obtained after criteria-based scrutiny. These articles are analyzed based on the type of publication. Figure 2.2 provides information on most effective article publications on safety culture topic. Key journals in the field are 'Safety Science (SS)', 'Journal of Construction Engineering

and Management (ASCE)', 'Journal of Management in Engineering (JME)' and 'Automation in Construction (AC)'. Among 51 scrutinized articles, 'Safety Science' publication is a significant contributor in publishing articles on safety culture topics of construction industry (n = 27).

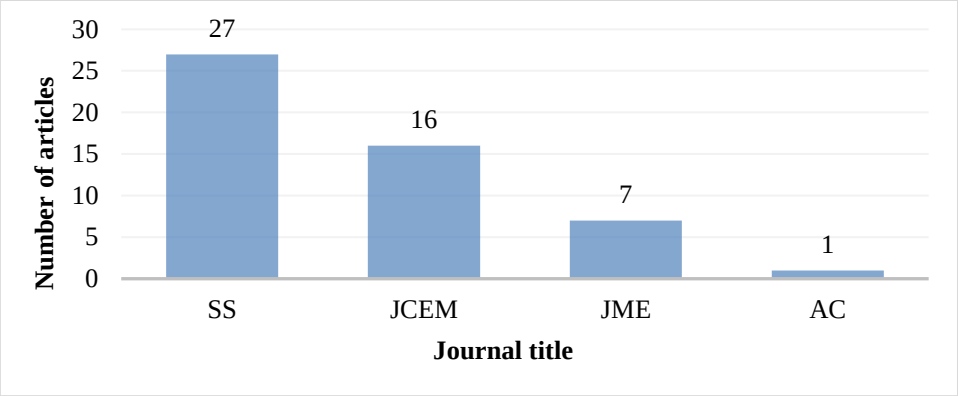


Figure 2.2 Article distribution by publications

In the last two decades, safety culture research has been extensively investigated and its publication outcomes are growing ever since. As indicated in Figure 2.3, the amount of safety culture articles subsequently increased from 2006. Then, there is a constant increase in growth rate of articles except in 2010, 2011 and 2014. Highest number of articles have been published in 2013 (n = 11) and 2015 (n = 9); with declining trend in 2014 (n = 1) and 2016 (n = 4). However, the development maturity point has already been reached in this particular area or field with lack of consensus on its features and concept of safety culture in construction industry.

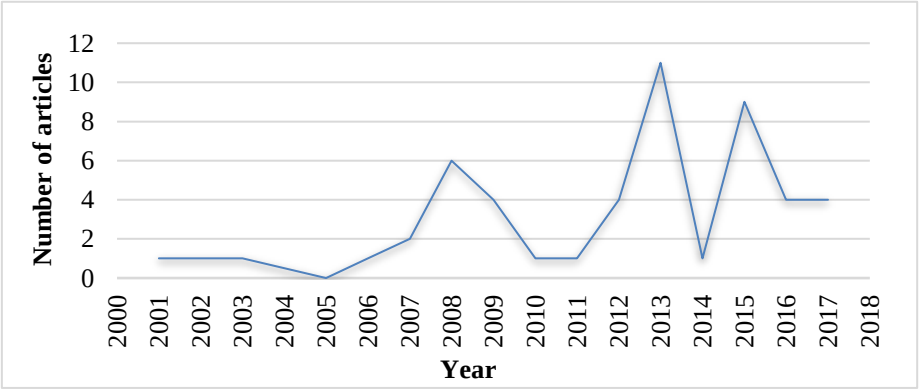


Figure 2.3 Article distribution by year of publication

Careful examination on cumulative number of articles over the years indicated that the importance of the topic has increased tremendously (Figure 2.4). This increased pattern can be compared with other safety-related articles as demonstrated in Li and Hale (2016). The publication output is increasing over the years and has become an important part of construction management research.

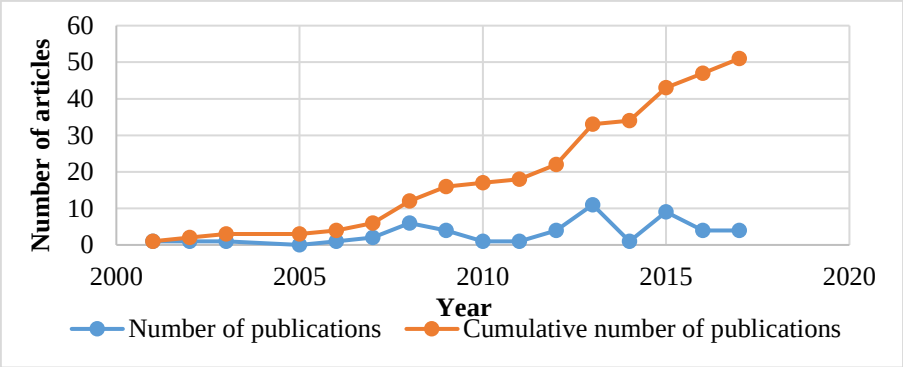


Figure 2.4 Cumulative article distribution by year of publication

Distribution of articles by country/region is analyzed and the articles are categorized based on the place in which the study was conducted, rather than merely the place of the authors. Safety culture articles related to construction industry were majorly from 16 different countries or regions and the worldwide distribution of the contributing countries or regions is shown in Figure 2.5. China has contributed with most articles (n = 10), followed by USA and Australia (n = 9), Hong Kong (n = 8) and India (n = 4). In these countries, there has been an increase in articles due to pressing concerns towards safety management in construction industry.

Figure 2.5 Country/region-wise distribution

2.4 SYSTEMATIC LITERATURE REVIEW ON SAFETY CULTURE RESEARCH

The last step of the proposed 3-step methodology is conducting a systematic literature review of existing safety culture research topics. Primary focus of conducting a systematic literature review is to have a complete overview of safety culture studies. The systematic literature review methodology that is structured outlines the concept of safety culture in construction industry (section 3.3.1.5). Firstly, the focus of systematic literature review is to provide an overview of defining the safety culture in construction organizations. Then, various safety culture factors that define the concept are examined. Lastly, the assessment tools for measuring the level of safety culture are highlighted.

2.4.1 Defining safety culture in organizations

The term safety culture was recognized soon after the Chernobyl accident (IAEA, 1986). However, no exact explanation of the term was provided for two main reasons: (i) several researchers highlight numerous safety culture elements as most significant, and (ii) culture of any kind is a tough thought to compactly outline. Some of the commonly used definitions that are believed to capture the essence of safety culture have been listed in Table 2.1.

Table 2.1 Safety culture definitions

Author and article	Definitions
Turner et al., (1989)	"Specific set of beliefs, norms, attitudes, roles, and social and technical practices within an organization which is concerned with minimizing exposure of employees, managers, customers, suppliers and members of the general public to conditions considered to be dangerous or injurious."
Pidgeon (1991)	"Human intermediation in the occurrence of accidents and catastrophes constituting a result of coincidence of various reasons."
ACSNI (1993)	"It is the product of individual and group values, attitudes perceptions, competencies, and patterns of behaviour that determine the commitment to and the style and proficiency of an organization's health and safety management."
Hale (2000)	Safety culture refers to "the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems."
Guldenmund (2000)	"Those aspects of the organizational culture that will impact on attitudes and behaviour related to increasing or decreasing risk."
Cooper (2000)	Safety culture is "that observable degree of effort by which all organizational members direct their attention and actions toward improving safety on a daily basis."
Mohamed (2003)	"A sub facet of organizational culture that affects workers' attitudes and behaviour in relation to an organization's on-going safety performance."
Fang and Wu (2013)	Construction project safety culture is defined as "A mixture of attitudes, beliefs, values, behaviours and norms held by the individuals and groups from different parties in a construction project (for both workers and management) team, and it is gradually formed and evolved in the construction project environment that would influence the commitment to, and the style and proficiency of how all parties involved in the project and its personnel act and react in terms of the ongoing safety performance."

Most definitions mentioned in Table 2.1 are analogous in their beliefs and perceptions with each of them focused on varying degrees in relation to safety. Even though the definitions differ from one another, yet there is common agreement that safety culture is being regarded as a proactive approach towards safety management.

Definitions mentioned in Table 2.1 are extracted from various disciplines (human psychology, healthcare sector, manufacturing sector, construction sector, etc.). Safety culture is deemed to be the observable degree of effort of all members who improve safety awareness and activities in daily life (Cooper, 2000), which can affect employee's attitude and behavior to consolidate safety performance of the organization. These observable features are represented by safety climate. Safety climate is therefore considered to be reflective of the "state" of the organization and hence, safety climate is a more tangible expression of safety culture (Kennedy and Kirwan, 1998). However, concept of defining safety culture in construction industry truly reflects the concept explained in other disciplines. Among these, the definition proposed by Fang and Wu (2013), has made an attempt in defining safety culture at construction project level. This seems to be more practical, as it clearly outlines the concept of safety culture in construction industry. Moreover, this indicated that the definition of safety culture is clear and clarified in the context of construction industry.

2.4.2 Factors affecting safety culture in organizations

Term analysis as explained in the earlier section (section 2.3.1) shows only the most occurring terms in a given text. But, a detailed analysis of terms is considered necessary for safety culture research that truly reflects the concept; which ultimately results in identifying the factors that affect safety culture.

In this regard, a comprehensive systematic literature review is done to determine the key factors influencing safety culture. Hence, this section focuses on identifying the factors that affect safety culture in various sectors. These factors signify a clear association existing among safety culture concepts and highlight the fundamental areas of safety management research (Niu et al., 2016). But it is challenging to comprehend the underlying interactions existing between the antecedents and consequences of safety culture research, as these influencing factors are not consistent but are

fragmented. Also, there exists little agreement on safety culture factors that suggests multiple features and complexity of safety culture concept.

Most safety culture models mainly address three dimensions to define the concept (i.e., personal, behavioural and situational). Various factors that affect safety culture are categorized under these dimensions. Detailed descriptions of safety culture dimensions with influencing factors are mentioned below:

i. **Personal factors:** This comprises of psychological aspects of individual and group values, attitudes and perception towards safety and describes "how people feel within an organization safety management system?" and is evaluated through safety questionnaires. Factors under this dimension include; co-worker's commitment to safety, worker involvement in safety, worker competence, and control, safety attitudes, trust among employees, sub-contractor involvement, and safety incentives and disincentives.
ii. **Behavioural factors:** This deals with actual ongoing safety-related actions and behaviours and describes "what people do within an organization safety management system?" and is evaluated through safety checklists. Factors under this dimension include; supervisor commitment to safety, risk management, safe work conduct, and workplace safety practices.
iii. **Situational factors:** This encompasses situational features that include policies, procedures, regulations, organization structure, and the management system. It describes "what the organization has or has to put in place?" and are evaluated through safety audits and inspections. Factors under this dimension include; safety policies, resources and training, management commitment to safety, organizational commitment to safety, safety communication and top management safety response.

A detailed list of articles that consider these factors under each dimension affecting safety culture is shown in Table 2.2.

Table 2.2 List of factors influencing safety culture dimensions

Dimensions	Factors	Authors and year of publication	Frequency
Personal	Co-workers commitment to safety	Burt et al., (2008); Colley et al., (2013); Fang et al., (2006); Feng et al., (2014); Fung et al., (2005); Gilkey et al., (2013); Gilkey et al., (2011); Healey and Sudgen, (2012); Kines et al. (2011); Liao et al., (2013); Liao et al., (2014); Lingard et al., (2012); Lingard et al., (2009); Lopez del Puerto et al., (2013); Melia et al., (2008); Teo and Feng, (2011); Zhou et al., (2011)	17
	Worker involvement in safety	Choudhry et al., (2009); Fang and Wu, (2013); Fang et al., (2006); Feng et al., (2014); Gillen et al., (2002); Hon et al., (2013); Kines et al., (2010); Niskanen, (1994); Pousette et al., (2008); Shen et al., (2014); Sparer et al., (2013); Teo and Feng, (2011); Tholen et al., (2013); Zhou et al., (2008)	14
	Worker competence and control	Chen and Jin, (2013); Chen et al., (2013); Dedobbeleer and Bedland, (1991); Fung et al., (2005); Kines et al., (2011); Liao et al., (2013); Shojii and Egawa, (2006); Teo and Feng, (2011)	8
	Safety attitudes	Siu et al., (2004); Zhou et al., (2008); Zhou et al., (2011)	3
	Trust among employees	Healey and Sudgen, (2012); Kines et al., (2011)	2
	Sub-contractor involvement	Molenaar et al., (2009); Molenaar et al., (2002)	2
	Safety incentives and disincentives	Molenaar et al., (2009); Molenaar et al., (2002)	2
Behavioural	Supervisor commitment to safety	Cigularov et al., (2013b); Cigularov et al., (2013a); Colley et al., (2013); Dedobbeleer and Bedland, (1991); Fang and Wu, (2013); Fang et al., (2006); Feng et al., (2014); Fung et al., (2005); Gittleman et al., (2010); Hoffmeister et al., (2014); Kapp, (2012); Kines et al., (2010); Liao et al., (2013); Lingard et al., (2012); Lingard et al., (2010); Lingard et al., (2009); Melia et al., (2008); Molenaar et al., (2009); Molenaar et al., (2002); Suninjijo and Zou, (2012); Teo and Feng, (2011); Zhou et al., (2008)	22

	Risk management	Dedobbeleer and Bedland, (1991); Fang et al., (2006); Feng et al., (2014); Fung et al., (2005); Gilkey et al., (2013); Han et al., (2014); Liao et al., (2013); Lopez del Puerto et al., (2013); Teo and Feng, (2011)	9
	Safe work conduct	Gilkey et al., (2013); Healey and Sudgen, (2012); Kines et al., (2010); Lopez del Puerto et al., (2013); Melia et al., (2008); Niskanen, (1994)	6
	Workplace safety practices	Arcury et al., (2012)	1
Situational	Safety policies, resources and training	Choudhry et al., (2009); Cigularov et al., (2013b); Cigularov et al., (2013a); Cigularov et al., (2010); Dedobbeleer and Bedland, (1991); Edelson et al., (2009); Fang and Wu, (2013); Fang et al., (2006); Feng et al., (2014); Fung et al., (2005); Gilkey et al., (2013); Gittleman et al., (2010); Glendon and Litherland, (2001); Han et al., (2014); Healey and Sudgen, (2012); Hon et al., (2013); Hon et al., (2014); Kines et al., (2010); Liao et al., (2014); Lopez del Puerto et al., (2013); Melia et al., (2008); Molenaar et al., (2009); Molenaar et al., (2002); Pousette et al., (2008); Shen et al., (2014); Suninjijo and Zou, (2012); Teo and Feng, (2011); Zhou et al., (2008); Zhou et al., (2011)	29
	Management commitment to safety	Abbe et al., (2011); Biggs and Banks, (2012); Choudhry et al., (2009); Cigularov et al., (2013b); Cigularov et al., (2013a); Dedobbeleer and Bedland, (1991); Edelson et al., (2009); Fang and Wu, (2013); Fang et al., (2006); Feng et al., (2014); Fung et al., (2005); Gilkey et al., (2013); Gilkey et al., (2011); Gillen et al., (2002); Han et al., (2014); Hon et al., (2013); Hon et al., (2014); Jorgensen et al., (2007); Kines et al., (2011); Liao et al., (2014); Lingard et al., (2010); Lopez del Puerto et al., (2013); Martin and Lewis, (2013); Pousette et al., (2008); Shen et al., (2014); Sokas et al., (2009); Sparer et al., (2013); Teo and Feng, (2011); Tholen et al., (2013); Zhou et al., (2008); Zhou et al., (2011)	31

	Organizational commitment to safety	Arcury et al., (2012); Chen and Jin, (2013); Chen et al., (2013); Cigularov et al., (2013b); Cigularov et al., (2013a); Colley et al., (2013); Feng et al., (2014); Gilkey et al., (2013); Glendon and Litherland, (2001); Han et al., (2014); Healey and Sudgen, (2012); Liao et al., (2013); Lopez del Puerto et al., (2013); Martin and Lewis, (2013); Mohamed, (2002); Molenaar et al., (2009); Molenaar et al., (2002); Niskanen, (1994); Teo and Feng, (2011)	19
	Safety communication	Cigularov et al., (2010); Fang and Wu, (2013); Feng et al., (2014); Fung et al., (2005); Gilkey et al., (2013); Glendon and Litherland, (2001); Hoffmeister et al., (2014); Kines et al., (2011); Lopez del Puerto et al., (2013); Martin and Lewis, (2013); Niskanen, (1994); Pousette et al., (2008); Probst et al., (2008); Siu et al., (2004); Teo and Feng, (2011); Tholen et al., (2013)	16
	Top management safety response	Gittleman et al., (2010); Lingard et al., (2012); Molenaar et al., (2009); Molenaar et al., (2002); Suninjijo and Zou, (2012)	5

Systematic literature review of articles is done to identify the factors affecting safety culture which is illustrated in Table 2.2. The categorization scheme for grouping each of the factors under safety culture dimensions are based on author's consideration of these factors in their safety culture studies. Further, based on the number of occurrence of these factors (i.e., frequency) in the articles, a radar chart is formulated as shown in Figure 2.6. Significance of formulating this chart points out a clear-cut identification of strong and weak zones of factors affecting safety culture.

From the chart (Figure 2.6), most influencing safety culture factors are: management commitment to safety (n = 31), safety policies, resources and training (n = 29), supervisor commitment to safety (n = 22), organizational commitment to safety (n = 19), co-worker's commitment to safety (n = 17), safety communication (n = 16) and worker involvement in safety (n = 14). These factors greatly influence the level of safety culture in any organization. Hence, more focus has to be given to these influencing factors for achieving a positive safety culture in the workplace.

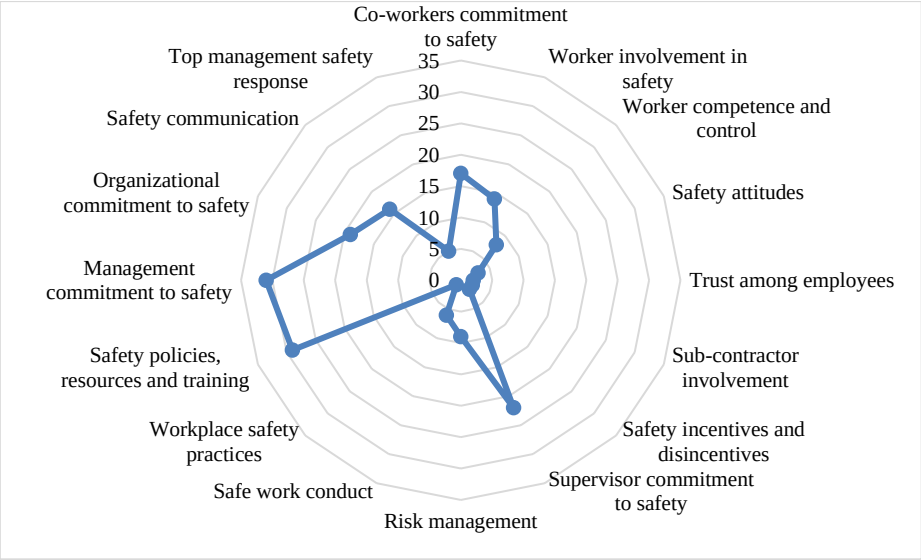


Figure 2.6 Distribution of factors affecting safety culture

Moreover, there exist discrepancy and disintegration of safety culture factors making it challenging to comprehend the fundamental concepts. Despite these conceptual differences, most authors use survey-based technique to identify and assess employees' perceptions regarding organizational issues by changing only the indicators or factors and evaluate considering that the core of safety culture construct proactively measures safety management (Cooper, 2016; Fleming et al., 2018). Hence, this review is undertaken to identify most commonly used factors in assessing safety culture of construction industry. These identified factors are categorized under the dimensions of safety culture namely; personal factors, behavioural factors, and situational factors. Measuring these factors serves to be instrumental in benchmarking the level of safety culture in any organization and acts as an indicator to compare safety culture between organizations (Gabryelewicz, et al., 2015). Most predominant factors that significantly assist in creating a positive safety culture are highlighted.

2.4.3 Assessment tools for measuring safety culture in organizations

Numerous safety culture definitions have brought to a greater extent for incorporating factors for developing measures of safety culture. Nevertheless, if on the one hand the literature on the theme has evolved in the conceptual manner, it further remains incipient regarding the creation of quantitative instruments for measuring and

evaluating safety culture at workplace that reinforce the importance to address the concept; and with a comprehensive approach to include technology, organizational and human aspects into consideration (van Nunen et al., 2018; Seo et. al., 2004; Seo, 2005; Reiman and Rollenhagen, 2014). As discussed in the previous section, there are various factors that affect safety culture considered in different sectors. Proper identification of measuring instruments is essential to assess safety culture in respective organizations. In real-time applications, one needs an effective measurement tool to measure the level of safety culture. Some of the instruments to assess the level of safety culture in different organizations with their features and limitations are enumerated in Table 2.3. The level of safety culture in different sectors is typically assessed through quantitative questionnaires which are based upon any number and combination of the factors mentioned in Table 2.2. Six most prominent tools to measure the level of safety culture in different sectors are shown in Table 2.3.

Table 2.3 Safety culture assessment tools

Instrument / tools	Industry	Features/highlights	Drawbacks / Limitations
Score Your Safety Culture Checklist	Transport and Medical Service	▪ Comprises of 20 statements. It is based on 'yes', 'no', 'I don't know' type answers. ▪ Convenient for interpreting the calculation based result and does not require an expert for using the checklist.	▪ Questions are complex and need necessary modification for applying to different industries.
Hearts and Minds programme – Understanding Your Culture Checklist	Energy, chemical, aviation, rail, marine, pharmaceutical, health care, defence and security, and manufacturing.	▪ Changes in the organization can be accounted for multiple features, like - Understanding Your Culture Checklist, SAFE (Safety appraisals for everyone) and Risk-assessment matrix. ▪ Consists of variety of instruments to assess safety culture which helps to recognize strong and weak points of health and safety.	▪ List is very descriptive in nature. ▪ Multiple features create confusion in users to choose the best approach in measuring safety culture. ▪ Not related to construction industry.

Safety Climate Assessment Toolkit and User Guide (LSCAT)	Offshore	▪ Comprises of 42 questions and adopts triangulation rule for assessment.	▪ Triangulation rule can be difficult for inexperienced professionals.
Safety Health of Maintenance Engineering (SHoME) Tool	Aviation	▪ Three different sets of survey instruments are developed for different management levels. This instrument can also be used for varying project sizes.	▪ Not universal and yet specially designed for aviation industry.
Nordic Occupational Safety Climate Questionnaire (NOSACQ-50)	Production and service sectors	▪ The survey consists of 50 questions. It is developed in different languages and is universal in nature and can be applied to different management levels and industry sectors.	▪ Involves complex questions and thus results are difficult to interpret.
Safety Climate Assessment Tool (S-CAT)	Construction industry	▪ Consists of 8 leading indicators that have been shown to predict employee injury rate. ▪ Responses to these indicators are provided with customized feedback report and give information on success areas and provide suggestions for improvements.	Advantages - ▪ Holistic approach ▪ Designed specifically for the construction industry

Most popular method for assessing safety culture is a perception survey (Choudhry et al., 2009; Mohamed et al., 2009; Zhou et al., 2010). This perception survey accounts to capture elements of safety culture which is based on the perceptions of employees of organizations (Guldenmund, 2007). Clear and positive perception about safety at workplace leads to development of positive safety climate and in turn enhances safety culture (Choudhry and Masood, 2011). Also, Mohamed (2003) recommended that safety culture deals with factors that have the ability to manage safety (top-down organizational attribute approach); whereas, safety climate deals with the view of front-line workers on the role of safety at the workplace (bottom-up perceptual approach). Survey instrument helps in determining the strengths and weaknesses of safety management practices being adopted in construction organizations.

Assessing the safety culture factors is essential to distinguish the level of safety culture in various sectors. Although, some of the ethnographic studies make the measurement approach difficult as they consume time and money. To overcome this, assessment tools are developed to measure the level of safety culture. Furthermore, this systematic literature review has helped to explore the concept of safety culture within construction industry in terms of formulation and advancement of safety culture research.

2.5 STUDY OF SAFETY CULTURE MODELS AND ITS ADVANCEMENTS

As discussed in section 2.1 of literature review, the concept of safety culture is not quite clear, even though it has been widely used for many years. For better understanding of this concept, a number of studies have been reviewed from the literature. Summary of safety culture research that is presented as safety culture models outlines the thought to be incorporated into the general practices of organization practices including the importance of safety management systems. Next section examines several safety culture models and reviews their relevance to the construction industry.

2.5.1 Safety culture models

Several researchers (Hofstede, 1991; Johnson and Scholes, 1999; Cooper, 2000; Guldenmund, 2010; Nielsen, 2014) have used the three-level model (Schein, 1992) to understand safety culture and explain the factors that influence it (Sorensen, 2002). Others have sought to clarify the relationship between safety culture and safety climate (Glendon and Stanton, 2000). They address how basic assumptions are manifested in beliefs and artifacts and observed behaviors and represent what is internalized by members of a company (Johnson and Scholes, 1999). They argue that basic assumptions are reflected in the policies, organization structure, monitoring systems, and organizational management. They use the concepts of Social Cognitive Theory to explain safety culture (Cooper, 2000); thus, creating equivalence for the three-level model (Schein, 1992). The lack of integration into general models of organizational culture is a significant shortcoming in most safety culture models. Organizational culture and safety climate have been identified as major catalysts to knowledge creation and sharing, and hence they are considered important dimensions of knowledge management research (Chen et al., 2004). Moreover, knowledge is affected by the

organizational culture as well as an individual's view point of organization practices (Liebowitza et al., 2003). Grote et al., (2000) presented a socio-technical safety culture that relates safety culture and safety management system to corporate structure. The model, however, is schematic and lacks the means to assess safety culture objectively. However, most commonly adopted safety culture models are discussed below.

2.5.1.1 Bandura's model of reciprocal determinism

Bandura's model of reciprocal determinism has been adopted to reflect the concept of safety culture in organizations (Figure 2.7).

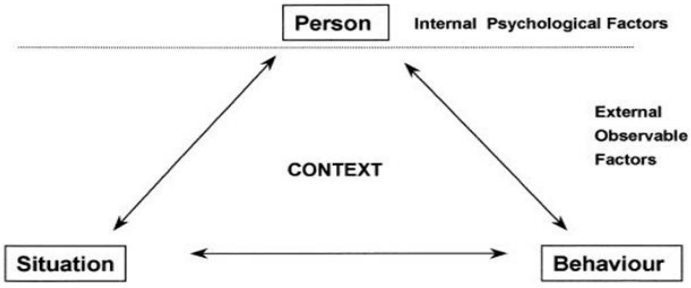


Figure 2.7 Bandura's model of reciprocal determinism

The model explains three basic dimensions that influence safety culture through reciprocal causation effects (Bandura, 1977), whereby the internal psychological influences of a person, the situation to which they are affected, and the behavior in which they intervene, all act as interacting factors that affect bi-directionally (Bandura, 1991). Further, Bandura (1991) states that this reciprocal influence does not mean that they occur simultaneously nor its influence has an equal effect but it takes sufficient time for causal factors to make an influence on the dimensions. For example, the bi-directional influence of person is affected by both working environment and management commitment towards work.

This model seems to offer the perfect framework to analyze organizational safety culture for several reasons. Firstly, the elements of personal, situational and behavioral dimensions reflect accident causal relationships precisely (Reason, 2016). Secondly, due to its dynamic nature, the measurement of individual and organization system is best suited to influence reciprocal relationship on every element (Dawson, 1992). Thirdly, it provides a 'triangulation' methodology' of influencing elements (Jick, 1979).

Lastly, it explicitly incorporates goal-setting paradigm advocated through the setting of sub-goals by developing task-strategies and setting self-regulatory processes (Bandura, 1991).

2.5.1.2 Cooper's reciprocal safety culture model

Alternatively, Cooper's reciprocal safety culture model is based on Bandura's model of safety culture that recognizes the presence of an interactive or reciprocal relationship between psychological, situational and behavioural factors of safety culture as shown in Figure 2.8. However, Cooper (2000) discusses that safety culture is the result of multiple goal-driven associations between personal, situational, and behavioural dimensions. Personal dimension is related to psychological aspects of an individual; situational dimension is related to organizational aspects; behavioral dimension coincides with job-related aspects. Individuals cannot be deterministically regulated or fully self-determined by their culture, but in a perpetual dynamic interaction, they can influence each other (Davies et al., 1992). However, Cooper (2000) suggested that the reciprocal safety culture model consisting of personal dimension can be assessed by safety climate questionnaires that capture attitudes and perceptions through perpetual audits; actual safety-related behaviors of individuals or group can be assessed by behavior sampling through safety checklists; and, lastly, situational dimension can be assessed through objective audits or inspections of safety management system of the organization. This reciprocal safety culture model has the ability to analyze safety culture and its associated components independently or in various combinations.

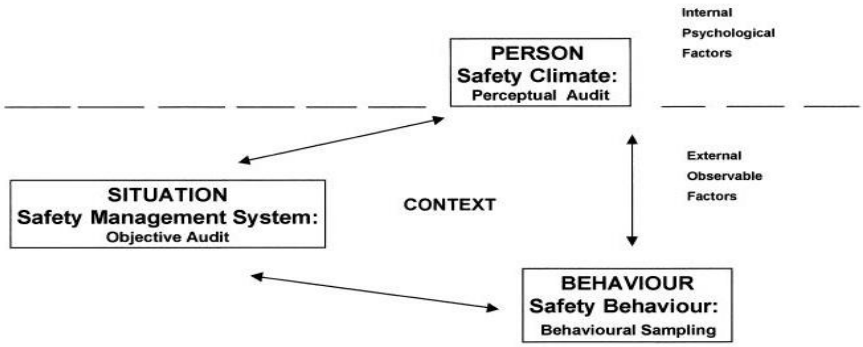


Figure 2.8 Reciprocal safety culture model

Researchers have carried out studies examining the relationship between safety culture, safety climate, and safety performance, wherein the foci of the models are on behavioural-compliance and participation individuals (Glendon and Litherland, 2001; Griffin and Neal, 2000). The main drawback of the presented model is individual participation within the organization.

2.5.1.3 Järvis and Tint reciprocal model of safety culture

The concept of the presented model (Figure 2.9) is also partly related to Reason's (2000) "informed (or safety) culture" model, which includes dimensions of reporting and learning culture. Works of Schulte et al., (2004) and Sherehiy and Karwowski, (2006) suggests that the concept and methods of knowledge management in the field of project and organization's implementation must be improved in order to improve the management of occupational health and safety processes. Role of management in maximizing workplace safety justifies its importance in linking management support, organizational climate and safety outcomes (Thompson et al., 1998). Need for the creation of knowledge management processes can be seen as a tool for improvement of safety culture and safety performance at small and medium enterprises (Jarvis et al., 2011, 2014). There is also a need for an effective knowledge management training-support system to provide an organization with strategic advantages that help in developing a learning environment, creating and maintaining skills in occupational health and safety; and hence it creates a positive safety culture within the organization (Jarvis et al., 2011, 2014). Essential factors that significantly enhance and strengthen occupational health and safety systems through knowledge management process are; communities of practice (CoP) and supportive and harmonized safety culture (Jarvis et al., 2014).

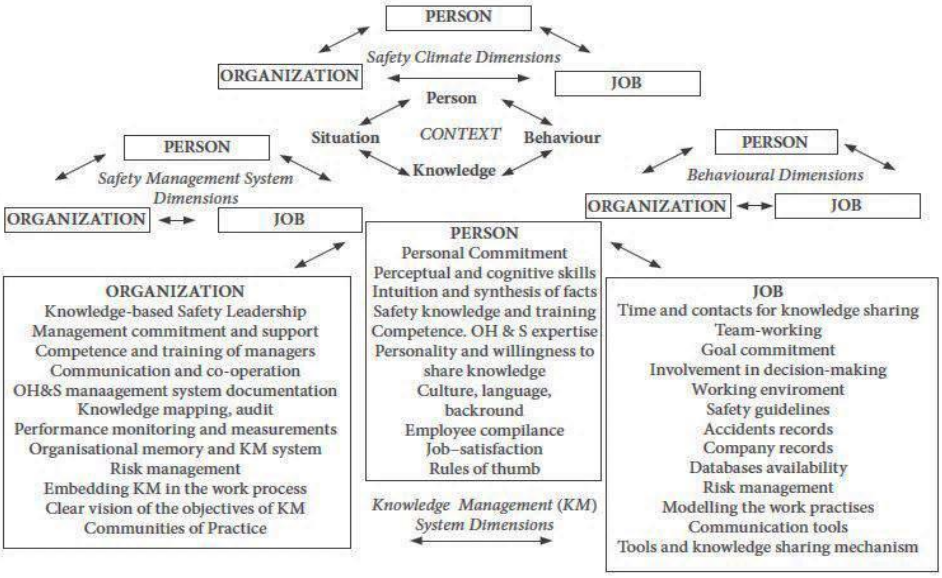


Figure 2.9 Reciprocal model of safety culture

Cultural benchmarking study can be deployed to make a comparison in terms of safety culture within the organization (Clarke, 2000) and it is effective in reducing risks (Rundmo, 2000). Health and safety culture survey tool helps to identify how employees think about the health and safety issues within their company (HSE, 1988) and provide a basis for improvements. This would be effective for the formulation of safety culture questionnaire and analyze the results based on its outcomes.

Poor safety practices have a greater impact on workers, their families, communities and the working company (Arboleda and Abraham, 2004). Benefits of improving occupational safety is to increase efficiency, competitiveness, productivity, and profitability by reducing injuries, incidents, accidents and illness rates (Chan et al., 2008; Hon et al., 2014). Effective documentation of the same cultivates necessary safety-related information and thereby knowledge within the organization (Rõa and Merisalu, 2010). Effective management of this safety-related information and knowledge within the organization requires proper dissemination (Nuñez and Villanueva, 2011). Also, it is found that there is greater potential for organizations to acquire information and knowledge, and adopt best practices from other organizations and authorities in the area of occupational safety (Järvis and Tint, 2009).

Table 2.4 Description of prominent safety culture models

Safety culture models	Description
Bandura's safety culture model (Bandura, 1991)	The model explains the three basic dimensions of safety culture, namely - person, behaviour, and situation that exhibits bi-directional influence on each other.
Cooper's safety culture model (Cooper, 2000)	The model highlights the assessment approach for each of the three dimensions that are required to quantify safety culture.
Teo and Feng's model of construction safety culture (Teo and Feng, 2009)	The model highlights that safety climate assessment could offer an authentic prediction of overall safety culture of construction organisation and has a significant influence on three dimensions of safety culture.
Reciprocal Model of Safety Culture (Jarvis et al., 2014)	The model integrates knowledge dimension into the general model of safety culture for improving the safety performance at small and medium enterprises of manufacturing sector.

Most safety culture models have common factors and dimensions, but it is not possible to state that there is a correct model. It is imperative to select the model that best fits the sector or organization. However, there is a consensus that working safety models must be multidimensional, but it is not specified exactly what dimensions these models should comprise (Fleming and Wentzell, 2008). The major shortfall with most safety culture models is that they do not include knowledge management aspects that enable safety culture to be embedded in organizational practice. By embedding knowledge management aspects, the dynamic interrelationship existing among safety culture factors at the enterprise level are addressed (Järvis et al., 2014). Most models highlighted in Table 2.4. discuss the consideration of dimensions attributed to the concept of safety culture from a general perspective, and are more or less not suitable to construction industry due to their inability to address the unique characteristics of construction projects. Also, they lack shared learning domains for essential safety training and learning prospects in organizations to aid knowledge management strategies. This is often essential for the distribution of safety information and knowledge that are necessary for effective management of safety in an organization (Järvis et al., 2014). Also, there is a lack of understanding about the role of knowledge management in improving safety culture of construction industry.

Moreover, there is growing potential for using the knowledge embedded within the organization as a vital resource in achieving the goals of occupational safety management (Gherardi and Nicolini, 2000; Sherehiy and Karwowski, 2006; Podgórski, 2010; Järvis et al., 2014). This majorly consists of managing implicit knowledge (knowledge stored in the individual's mind) and explicit knowledge (knowledge stored in manuals, policies, and databases). Knowledge management in organizational safety is essential to minimize duplication of work and to ensure the information that is easily available without any hindrance (Nuñez and Villanueva, 2011). This management process includes acquisition, storage, and dissemination of safety-related knowledge. Hence, there is a need for integration of occupational safety policy with safety culture aspects of the organization. The process of knowledge management contributes to support the development of safety culture in the organization (Gaureanu et al., 2016). However, the need to consider knowledge as a dimension in achieving positive safety culture in construction industry is missing in the literature. This establishes a need to formulate an integrated approach to incorporate knowledge dimension in safety culture studies. In this regard, it is hypothesized that knowledge dimension has a significant relationship with personal, behavioural and organizational dimensions that could improve safety culture in construction industry.

2.5.2 Construction safety culture

Construction is one of the hazardous industries in which accidents, injuries, fatalities, and other work-related illnesses result in severe direct and indirect losses (Fang et al., 2013). The cost of an accident increases compensation cost, loss in productivity, and causes delays (Hinze, 2000). There is undeniable reduction in work performance due to loses or injuries of trained and experienced workers and consequent delays in work progress delays. Traditional safety measures rely on data from accidents and injuries. Another method is behavioural sampling, which involves monitoring of actions which allows one or more qualified observers to observe on-site workers to assess whether they are working safely or unsafely. Most importantly, aim of safety management research is to forecast safety-related outcomes in order to provide valuable guidance to improve organizational safety. This requires extensive knowledge about how and what influences safety at the workplace (Choi et al., 2017).

In general, safety management is regarded as the documented and formalized system (policy, procedures, training, instructions, and resources, etc.) of controlling against risk or harm (Kennedy and Kirwan, 1998; McDonald et al., 2000). Nonetheless, the standard of safety management systems of an organization as they exist on paper does not necessarily reflect how they are implemented in practice. This is where the concept of safety culture comes into the picture. It is the organizations' safety culture that influences the effectiveness of the resources, policies, practices, and procedures for safety management as they represent the work environment and employees' underlying perceptions, attitudes and usual practices at all working levels (Kennedy and Kirwan, 1998). The model proposed by Choudhry et al., (2007) emphasizes construction safety culture which assesses, maintains and improves safety culture and reflects the efficacy of safety management systems at project sites.

Safety culture is becoming critically important to health and safety of employees operational in construction projects (Choudhry et al., 2007). Safety culture is affected by safety behaviour to a greater extent (Clarke, 2000) and there exists a positive relationship between consequences of safe work behaviour and safety climate at the workplace (Mohamed, 2002). A lot of studies have shown that the safety behavior of workers is affected by their understanding of safety policies, procedures and practices and this is referred to as safety climate (Zohar 1980; Neal et al., 2000; Mohamed 2002; Clarke and Ward, 2006; Zhang et al., 2016). Awareness of the impact on safety performance of organizational and social factors has resulted in a wide range of research on safety culture and safety climate (Flin et al., 2000; Guldenmund, 2000). Teo and Feng (2011) shows an empirical examination of the relationship between safety climate and safety culture and emphasizes that assessment of safety climate could provide a reliable prediction of the level of the overall safety culture of a construction organization. These measurable safety climate dimensions have a definite relationship to personal characteristics of the individual that could improve safety culture in construction industry (Fang et al., 2006). Safety climate can be measured by developing a safety culture questionnaire (Cooper, 2000). Hence by developing a safety culture questionnaire, cultural aspects in relation to safety can be measured in construction organizations. Use of questionnaires has a significant impact on measuring safety

culture factors namely; psychological factors, behavioural factors, and organizational factors. In summary, general agreement on the concept of safety culture in construction has been reached, and yet there is some agreement on its influencing attributes. Employees and the organization could benefit to a greater extent if unanimity could be established on its measurable attributes.

2.6 SAFETY CULTURE AND KNOWLEDGE MANAGEMENT ASPECTS

2.6.1 Knowledge management in organizations

Knowledge management process is defined in terms of supply chain through processing the data, managing the information, evaluation, and synthesis of processed data that leads to development of knowledge, and finally sharing among its users (Shih et al., 2006). Also, knowledge management is based on a strategy aimed at establishing knowledge as an integral and appropriate tool for achieving business objectives. The goal of knowledge management is to establish an organizational structure and culture that facilitates and encourages the creation of knowledge by acquiring collective knowledge and solving problems (Shih et al., 2006). The strategy to develop knowledge management is to integrate the process within the corporate culture of the organization. Hence, it is important to form a culture of knowledge sharing that is supplemented by both information technology and the people. Benefits of knowledge management can play a critical role in building the strategic management of human capital and leverage its knowledge base for business performance and its improvement (Goel et al., 2010).

Among different societies, businesses and in the academic world, it is accepted and declared that, 21st century is the era of the knowledge economy and knowledge is one of the most powerful tools used by organizations to maintain competitive advantage, improve business and productivity of employees. One of the most prioritized tasks for organizational structures has become the strengthening of organizational abilities and making sure that knowledge management is effective in achieving organizational goals. Dynamic, extreme, constant and continuous changes are characterized in these days where the environment possessing knowledge is becoming one of the most important economic resources. These resources determine the stability of the organizations, improve operational efficiency and build competitive advantage in modern

organizations. For this, effective knowledge management, training and implementation strategies need to be done. It is almost impossible to make sure that knowledge is being shared without proper organizational culture. The essential task of leaders working in organizational structure in the context of knowledge management is to ensure such an environment in which members of the structure are motivated to acquire, develop, share and use knowledge for reaching common organizational goals.

Knowledge management itself cannot consolidate or prosper in an organization without human input and does not flourish if a person does not interact. People's desire to share knowledge and experience depends on their will and therefore, the role of leaders in effective knowledge management is undeniably important for any organization. Leadership influences organizational culture in creating favourable environment and thus supports the process of knowledge management. It is almost impossible to make sure that knowledge is being shared without proper organizational culture. Therefore, a proper organizational culture ensures the process of knowledge management to be effective for reaching common organizational goals. Analogous with safety, effective change towards identifying, capturing, storing and transferring of safety knowledge plays a prominent role in construction organization (Hallowell, 2011).

2.6.2 Role of safety knowledge in organizations

Safety knowledge can be conceptualized as 'an employee's understanding of organization's safety procedures' (Gaureanu et al., 2016) that includes understanding of safe operating procedures and possesss adequate safety training and instructions (Hofmann et al., 1995). Gressgård (2014) argued that knowledge possessed by individuals has to be converted into a general form that can be understood, absorbed and applied by other individuals. Sharing of knowledge is also known as the contribution or the reception of project information (Saedi et al., 2019). In this regard, good safety practices will lead to a safe working environment and encourage others to adopt these safe practices through safety training at the workplace. Employees believe that efforts to reduce injuries and workplace incidents in carrying out their work should be made in compliance with the safety rules and regulations, and this ensures safety at all times. Nevertheless, very little attention has been paid to the process of exchanging

knowledge related to safety and this can be looked upon by creating a suitable organizational structure to increase the efficiency of safety-knowledge (Järvis et al., 2014). More importantly, sharing of information and knowledge related to safety aspects is important for management of health and safety in the organization.

2.6.3 Need for integration of knowledge management in occupational health and safety

Most important resource in achieving the goals of OHS management (Occupational Health and Safety) is managing knowledge in the organization. This majorly includes the management of individual knowledge (i.e., personal knowledge), structural knowledge (i.e., knowledge stored in records, databases, manuals, reports, etc.) and lastly, organizational knowledge (i.e., activities involving learning process in the organization) (Järvis et al., 2014). The principle that defines occupational health and safety management in the organization can be effective only if it is integrated into the overall management functions of the organization structure (Podgórski, 2010). The drivers of organization innovativeness are knowledge creation and sharing (Chen et al., 2010), which can be moderated by organizational climate (supportive climate, innovative climate) or organizational structure (less formalized, less centralized and more integrated). When the organizational structure is less formalized, more decentralized and integrated, knowledge management is more enhanced (Chen et al., 2010). Whereas, safety knowledge can be analyzed only through centralized management in order to create knowledge applicable to the improvement of workplace safety (Nuñez, 2011). Also, Firoozi and Hatami (2017) found that knowledge is an important source of capital for an organization and can only be created and managed in a healthy cultural environment.

Knowledge management in organizational safety is essential so that duplication of work is reduced and thus ensures the required information is easily available without any hindrance (Nuñez and Villanueva, 2011). This management process includes acquisition, storage, and dissemination of safety-related knowledge that represents the firm's safety capital (Nuñez, 2011). The role of knowledge methods is critical for ensuring efficient OHS management (Shih et al., 2006). Role of tacit knowledge in the

workplace is to build workers and managers' awareness of hazards and risks and if it is properly managed and efficiently disseminated, it contributes to the shaping of safety culture within the enterprise (Podgórski, 2010) and promotes cultural values to the organization (Shih et al., 2006).

Activities attributed to OHS show that all necessary preventive measures taken would support better control (elimination or reduction) of the risks associated with the work processes. A significant contribution to avoiding accidents and related costs, which can even contribute to bankruptcy, is linked to the well-defined OHS culture and its implementation (Gaureanu et al., 2016). Moreover, the process of knowledge management supports the development of OHS culture in the organization (Figure 2.10).

Figure 2.10 Need for knowledge-based safety culture (Gaureanu et al., 2016)

Hence, there is a need for integration of occupational health and safety policy with the safety culture aspects by measuring individual behaviour (safety audits) and organization management systems.

2.7 SIGNIFICANCE OF KNOWLEDGE MANAGEMENT IN SAFETY MANAGEMENT

The critical challenge possessed by OHS in regards to construction industry is management of the existing individual (tacit) knowledge, explicit knowledge, and organizational knowledge. Explicit knowledge mainly consists of - knowledge that is codified into regulations, instructions, standards, reports, manuals, guidelines, and databases. Tacit knowledge mainly consists of – attitudes, perceptions, experience, thumb rules, intuitions, hazard recognition ability etc. Knowledge areas constitute about 26% that are stored on papers, about 20% stored in digital form, and over 42% are believed to be in the minds of employees (Sherehiy and Karwowski, 2006).

The systematic development of organizational knowledge is vital in the area of OHS management as it contains the specific experiences and successful hazard prevention measures with respect to previous safety-related issues. Collection of competencies, information, knowledge, and experiences related to OHS are stored as organizational knowledge to be able to provide organizational members with access to relevant resources. For example, the safety program synthesizes various occupational safety viewpoints that include the incorporation of different OHS-related knowledge assets. This, in turn, includes the growth of organizational knowledge with ongoing organizational learning process at all levels of management. Furthermore, this establishes a significant link and a definite correlation between knowledge management types and safety culture elements. Detailed list of attributes and their relationship are presented in Table 2.5.

Table 2.5 Significant link between knowledge management types and safety culture elements

Tacit knowledge	**Explicit knowledge**	**Organization knowledge**
Safety engineer's experience	Accident records	Organization learning
Safety hazard recognition	Safety regulations (OSHA-USA)	Communities of practice
Related to practical aspects	Safety guidelines	Knowledge-Based System (KBS)
Perceptual and cognitive skills	Theories and axioms	Competence and training
Physical experience	Company records	OHS management system documentation
Rules of thumb	---	---
Intuition and synthesis of facts	---	---

Source: ILO-OSH, (2001)

The dimensions of safety culture can be exactly mapped to the types of knowledge management based on the previous discussion. The safety culture model (Figure 2.11) and the knowledge management model (Figure 2.12) exhibits a definite relationship, which is shown below:

Tacit knowledge ⟺ Psychological factors of safety culture

Explicit knowledge ⟺ Behavioural factors of safety culture

Organizational knowledge ⟺ Organizational factors of safety culture

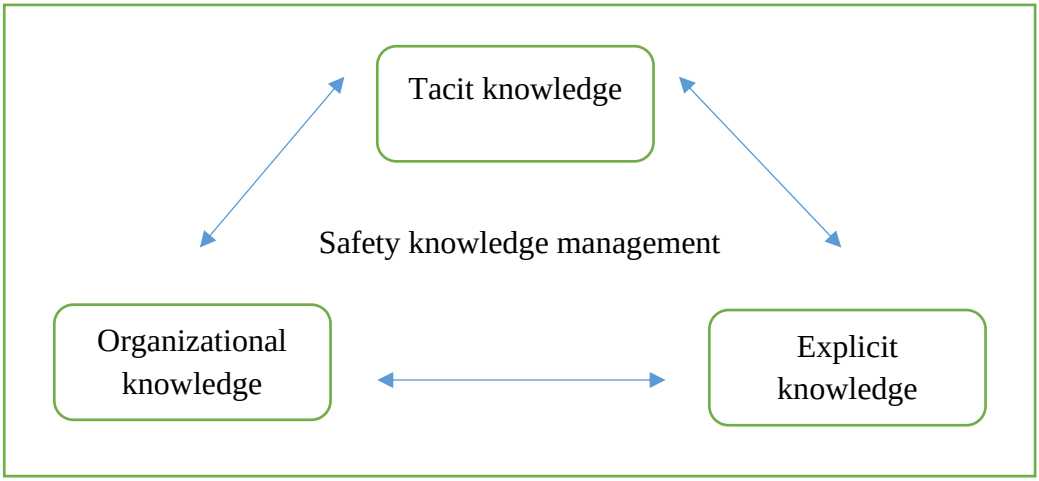


Figure 2.11 Model showing interrelationship between safety culture dimensions

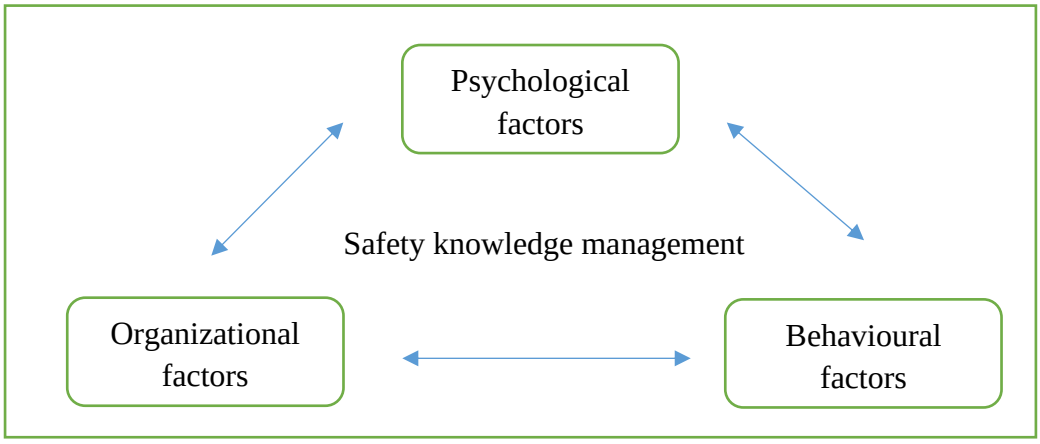


Figure 2.12 Model showing interrelationship between types of knowledge management

The main goal of knowledge management in the area of OHS is to support safety culture, which enables and rewards the creation of OHS knowledge through collective knowledge acquisition and mitigating problems. Thus, the management of OHS along with knowledge management must ensure a suitable environment for knowledge sharing and suggest new ways of using existing knowledge.

2.8 SIGNIFICANCE OF KNOWLEDGE MANAGEMENT IN SAFETY CULTURE STUDIES

Despite the improvement of digital technologies in enhancing construction safety management, human-factor related issues such as individual perceptions, attitudes, and behaviour in safety cannot be downplayed. Recent studies have embraced safety management methodologies that address these human-factor related issues by defining safety culture. However, management of employee's perception of safety on attitudes, behaviours, and practices facilitate knowledge aspects and thereby enable safety culture to be embedded in organization practices. More importantly, effective dissemination of this knowledge shapes safety culture within the organization (Järvis et al., 2014). Main reason that causes accidents and incidents is attributed to poor safety culture in construction industry (Choudhry et al., 2007). Effort to assess working safety culture is therefore highly important to create a safe working environment and eventually to minimize work injuries in construction industry (Machfudiyanto et al., 2017). Therefore, emphasis on improving safety culture assists organizations to improve their performance by minimizing the rate of accidents; improves the reputation of industry; and increases safety at the workplace (Kartam et al., 2000).

Safety culture has become critically important within the construction site environment for safety of employees involved in the work (Choudhry et al., 2007). Even though the concept of safety culture is relatively new within the construction industry, it is gaining popularity because it uses proactive measures, upstream, or leading indicators such as measurement of safety climate (Flin et al., 2000; Mohamed, 2002). Safety culture, as defined by Fang and Wu (2013) with respect to construction project environment is "a mixture of attitudes, beliefs, values, behaviours, and norms held by the individuals and groups from different parties in a construction project team for both workers and management, and it is gradually formed and evolved in the construction project environment that would influence the commitment to the style and proficiency of how all parties involved in the project and its personnel act and react in terms of ongoing safety performance". Safety culture is deemed to be the degree of observable effort of individuals who improve safety awareness and activities in daily life (Cooper, 2000)

which can affect employee's attitudes and behaviour to consolidate safety performance of the organization.

The working nature of construction industry is mainly through projects that are transitional. Knowledge and experience are lost when projects come to completion (Esmi and Ennals, 2009). Lack of knowledge management strategies in safety-related issues causes a loss in knowledge that is gained in the project (Grover and Froese, 2016). These missed opportunities for learning trigger recurrence of accidents (Gressgård, 2014); and it is believed that effective implementation of knowledge management strategies in construction projects could mitigate this phenomenon of accident repeatability.

2.9 FACTORS AFFECTING KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION INDUSTRY

Safety performance assessment has been measured to date by reactive or lagging indicators or post-accident analysis. However, these outcomes-based assessments have significant drawbacks such as ignorance of risk exposure, inaccurate reporting, and variability in accident severity. Accidents or incidents-based indicators are generally regarded as less reliable to measure workplace safety as these indicators represent random variations of accident figures and varying reporting practices (Khosravi et al., 2014). However, in recent times, there has been an increase in interest regarding proactive or leading indicators (Shea et al., 2016; Givehchi et al., 2017); as these focus on cause and accident prevention, such as hazard identification, behaviour-based safety, and safety culture.

Safety culture has been identified as a critical element for assessing safety in the workplace. In this regard, there are limited studies that provide a detailed list of measuring indicators or items (Biggs et al., 2010; Schwatka et al., 2016; Akroush and El-adaway, 2017). In addition, there has neither been an agreement on the number of factors that are required to quantify safety culture nor on which factors are the best. Safety culture and factors involved change based on the location of the investigation. A questionnaire developed in one country or region for investigation would not be sufficient to collect data in another. There is lack of literature on the role of knowledge

management strategies in improving safety culture of construction organizations and the only way to start investigations in such an environment is to adopt methodologies developed in earlier researches, with an intention to adapt it to construction industry settings. Keeping the contextual differences in mind (place of study), it is practically impossible to build up an empirically grounded knowledge-based safety culture model in a particular social setting and anticipate that this model will have ecological validity. Furthermore, diversity of construction stakeholders from different parts of the nation is required to achieve one universal safety culture survey instrument that, after having its ecological validity confirmed, could be used all over the country. Hence, in this regard, the intention of proposing an inventory of knowledge-based safety culture factors is necessary. Summary of factors under each dimension or constructs for developing overall safety culture in construction industry is as shown in Table 2.6.

Table 2.6 Factors affecting knowledge-based safety culture in construction industry

Constructs/ dimensions	Factors	Selected articles
Psychological dimension (P1-P14)	Personal commitment(P1), job satisfaction(P2), relationship among co-workers(P3), culture, language and background of an individual(P4), adaptability to new systems(P5), employee compliance(P6), personality and willingness to share safety knowledge(P7), safety knowledge and training competence(P8), financial incentives(P9), employee recognition(P10), involvement in or exposure to safety-related issues(P11), participation/involvement in safety performance evaluation(P12), Occupational Health & Safety expertise (OH&S) expertise(P13), safety-mentoring process(P14)	Carillo et al., (2004); Cooper, (2000); Järvis and Tint, (2009); Hallowell, (2011); Järvis et al., (2014); Sherehiy and Karwowski, (2006)

Behavioural dimension (B1-B16)	Personal responsibility(B1), co-workers peer support(B2), team working(B3), commitment towards organization's safety goals(B4), better and safe working environment(B5), safety communication tools(B6), safety plans(B7), internal safety department(B8), time and contacts for safety knowledge sharing(B9), involvement in decision-making process(B10), embedding safety knowledge management in work process(B11), risk management(B12), modelling safe work practices(B13), safety knowledge management program(B14), proprietary orientation and training(B15&B16)	Carillo et al., (2004); Cooper, (2000); Järvis and Tint, (2009); Hallowell, (2011); Järvis et al., (2014); Sherehiy and Karwowski, (2006)
Organizational dimension (O1-O23)	OH&S management system(O1), information technology and human resource management(O2), clear vision and shared values(O3), leadership(O4), safety competence and training(O5), clear visions of safety knowledge management objectives(O6), safety compliance(O7), managing conflict(O8), management commitment and support(O9), communication and feedback mechanism(O10), communities of practice(O11), safety planning(O12), safety resource allocation(O13), regular discussion/meetings(O14), organization training and safety programs(O15), safety knowledge storage(O16), safety performance metrics(O17), safety knowledge sharing mechanism(O18), organization safety knowledge effectiveness(O19), organizational memory(O20), knowledge mapping tools(O21), investment and budgetary requirements(O22), ease of access and retrieval of stored safety knowledge(O23)	Carillo et al., (2004); Cooper, (2000); Hallowell, (2011); Järvis and Tint, (2009); Järvis et al., (2014); Loforte Ribeiro, (2009); Sherehiy and Karwowski, (2006); Smith-Crowe et al., (2003); Teo and Feng, (2009)
Knowledge dimension (K1-K16)	Accidents records(K1), safety regulations(K2), safety guidelines(K3), company records(K4), safety databases(K5), accident analysis and self-inspections(K6), occupational health and safety policy(K7), safety documentation system(K8), safety engineer's experience(K9), safety hazard recognition(K10), relatedness to practical aspects(K11), perceptual and cognitive skills(K12), physical experience(K13), thumb rules(K14), safety facts(K15), learn and share values(K16)	Carillo et al., (2004); Hallowell, (2011); Järvis and Tint, (2009); Järvis et al., (2014); Owusu-Manu et al., (2018); Podgórski, (2010); Sherehiy and Karwowski, (2006); Smith-Crowe et al., (2003)

2.9.1 Implications from literature review

Section 2.6, 2.7 and 2.8 imply the importance of using knowledge management strategies in safety culture studies. Summarizing the studies carried out from previous researchers has also underlined the importance of employee's attitude and perception towards safety (known as safety climate) as a part of safety culture that aims for creating a learning environment and implies a means to change employee's behaviour to enhance safety culture (Gaureanu et al., 2016). This supports the development of an inventory of safety culture factors in relation to knowledge management strategies. Therefore, it becomes imperative to study the contributary factors affecting safety knowledge in construction industry. Ultimately, there is a need to distinguish a satisfying safety culture model with added knowledge dimension, which is a neglected dimension among other dimensions of safety culture and hence it can be developed as a framework in construction industry.

Detailed list of factors presented in Table 2.6 is categorized under the context of safety knowledge that emphasize the implication of knowledge dimension towards developing overall safety culture in conduction industry. All these factors are believed to have an impact on measuring safety culture of construction industry. Since safety culture is a subset of the organization culture (Choudhry et al., 2007), the need to measure these factors is inferred from the literature and serves as an effective assessment tool that affects overall organization culture (Teo et al., 2009). The highlighted dimensions with contributory factors are considered critical and its relevance to construction industry is carefully analyzed.

2.9.2 Purpose of the proposed model

The purpose of the proposed model can be studied separately or in several combinations to measure the influence on the achievement of sub-goals (e.g. measuring the variables as an antecedent to measure the dimensions) that helps to attain its super-ordinate goals (i.e. creating a safety culture/developing a positive safety culture), and direct towards goal achievements arising from the creation of an organization's safety culture. Therefore, in order to validate the assessment of safety culture dimensions with contributary factors that have an impact on overall safety culture, hypotheses are

postulated as; (i) psychological factors under the influence of safety knowledge management have an impact on overall safety culture, (ii) behavioural factors under the influence of safety knowledge management have an impact on overall safety culture, (iii) organizational factors under the influence of safety knowledge management have an impact on overall safety culture and (iv) knowledge dimension (comprising of tacit and explicit knowledge factors) has an influence on overall safety culture.

2.10 RESEARCH HYPOTHESIS

Reciprocal interactions existing among psychological, behavioural and organizational dimensions that have been recognized and are reflected in majority of safety culture models are discussed in detail in previous sections. It is perceived that addition of 'knowledge dimension' as indicated along with other three safety culture dimensions is required to measure overall safety culture of construction organizations. Further, it is also possible to break down the elements of knowledge dimension to exhibit similar reciprocal relationships with other safety culture dimensions as explained in previous safety culture studies (Cooper, 2000; Järvis et al., 2009; Järvis et al., 2014).

Therefore, in order to validate the assessment of knowledge dimension that has an impact on measuring the overall safety culture, four hypotheses are postulated (Figure 2.13):

H1: The *psychological* factors under the influence of safety knowledge management have an impact on the knowledge dimension that contributes to the measure of overall safety culture.

H2: The *behavioural* factors under the influence of safety knowledge management have an impact on the knowledge dimension that contributes to the measure of overall safety culture.

H3: The *organizational* factors under the influence of safety knowledge management have an impact on the knowledge dimension that contributes to the measure of overall safety culture.

H: The knowledge dimension along with other safety culture dimensions has an influence on the overall safety culture.

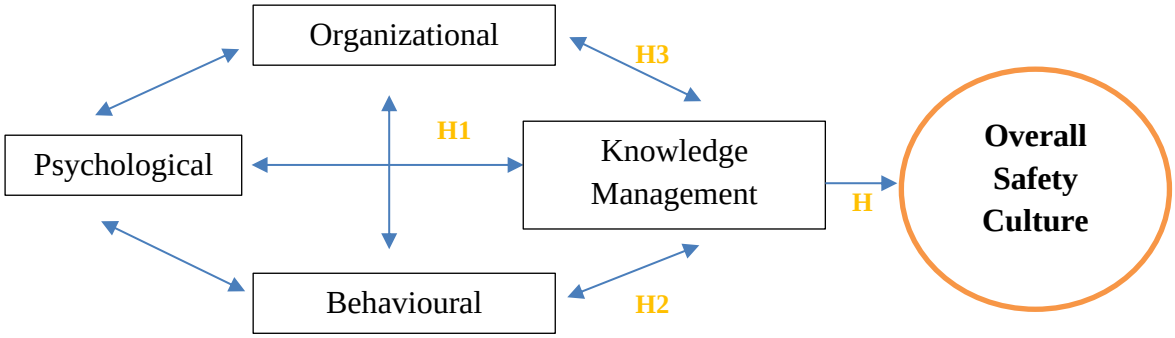


Figure 2.13 The theoretical model

The concept of formulating a model does not involve reinventing the wheel involving several moderators and mediators that influence the achievement of the objective that have already been identified as research objectives (i.e. safety culture models). Therefore, a goal-setting paradigm has been developed with the view that the creation of safety culture with knowledge dimension as a super-ordinate goal; which is achieved by developing and pursuing multiple sub-goals that deal with factors that influence these dimensions to measure overall safety culture. Conceptual model for integrating knowledge dimension in safety culture model under the influence of safety knowledge is as shown in Figure 2.13.

Based on identification of safety culture factors related to safety knowledge in construction industry as mentioned in section 2.9, an inventory of safety culture factors is articulated. From this, a conceptual framework of overall safety culture with influencing factors is formulated (Figure 2.14). This model is further tested with both qualitative and quantitative approaches. The proposed model explains four dimensions that influence safety culture in terms of triadic reciprocal causation where the influence is bi-directional. Reciprocity of factors does not mean that the reciprocal influences occur simultaneously nor its influence has an equal effect but it takes sufficient time for causal factors to make an influence on the dimensions. Based on identification of safety culture factors related to safety knowledge in construction industry as mentioned in the earlier section, a conceptual framework of overall safety culture with influencing factors is formulated and is shown in Figure 2.15.

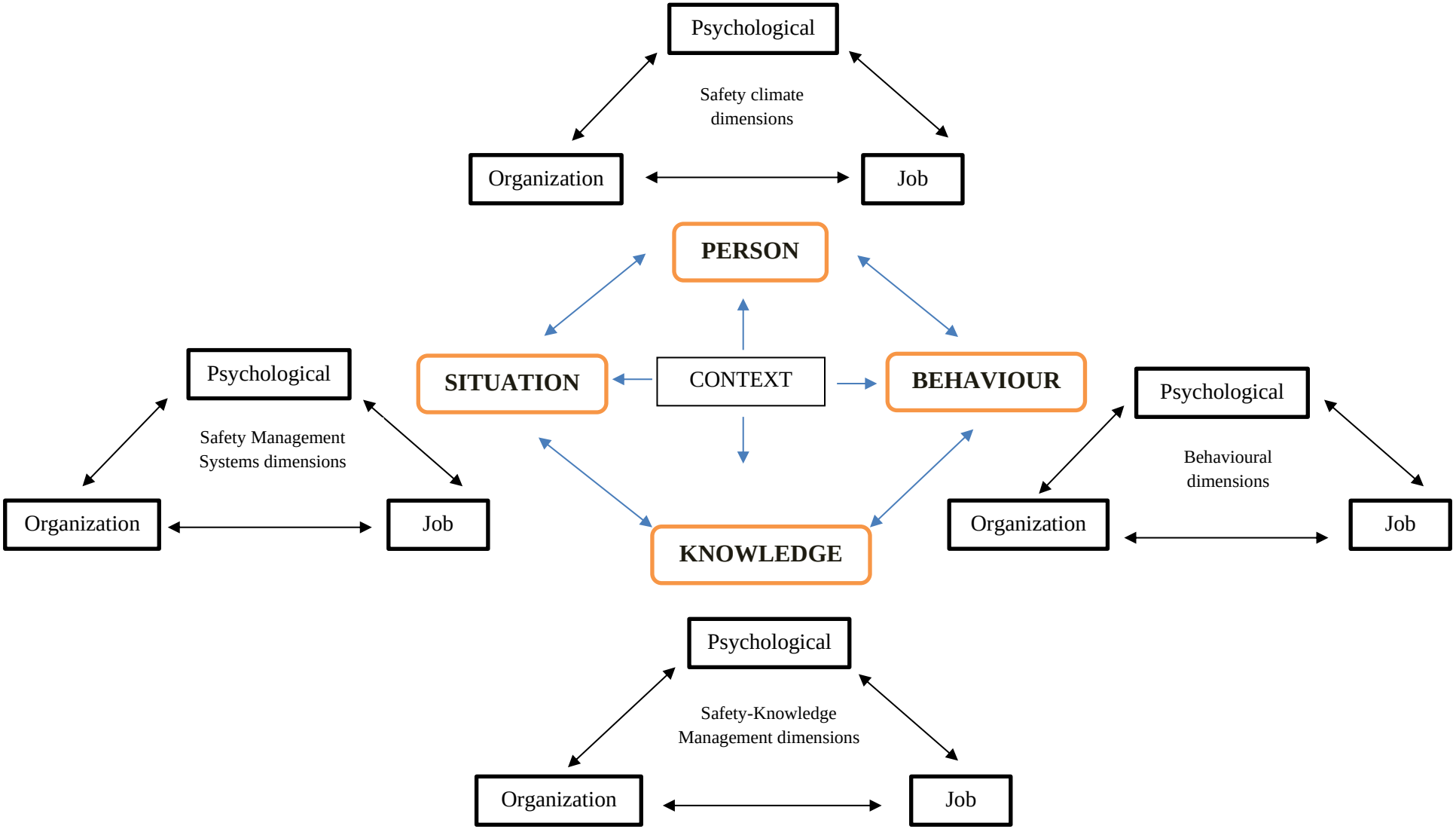


Figure 2.14 Proposed conceptual framework of safety culture

Figure 2.15 Conceptual framework of overall safety culture with influencing factors

2.11 CHAPTER SUMMARY

This chapter has provided a good foundation for understanding of development of safety culture research in construction organizations. A detailed overview encompassing the recent trends and advances is explored through a systematic literature review. The conception of safety culture in relation to its definition, contributory factors and assessment tools for evaluating safety culture in construction organizations have been discussed in detail. This chapter has reviewed several safety culture models and its advancements to formulate research objectives of the study. Finally, the significance of integrating knowledge management aspects to improve safety culture among construction organizations has been addressed. In short, this chapter has provided a concrete foundation to fulfill the objectives of the study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the research design and explains the various steps undertaken to attain the objectives of the research. The choice of appropriate research design and techniques that are relevant to this research study are explained. This chapter also clarifies the rationale for the selected research methodology. Explanation for the techniques and methods used to collect data, analyses, and interpretation are further depicted.

The research methodology adopted is based on a thinking framework that is initiated by formulating a theoretical framework based on endorsed theories of the previous related researches. In this regard, deductive analysis is carried out as established through operational research model as shown in Figure 3.1.

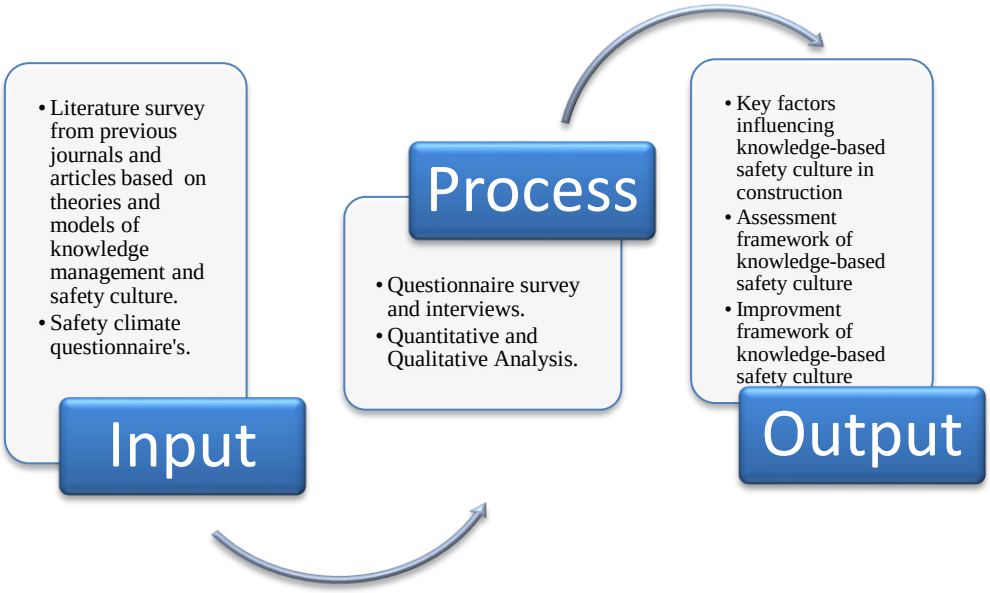


Figure 3.1 Operational research model

3.2 REVIEW OF RESEARCH METHODS

Research in the field of construction management is based on a wide range of disciplines such as social sciences, natural sciences, management and engineering (Dainty, 2008; Fellows and Liu, 2008). In order to establish the requirement of context in a specific field, a suitable research design is essential to drive the research questions. Research design is defined as a plan or proposal for the conduct of research (Creswell, 2013), which guides the whole research process systematically and helps in finding answers to the research questions. It comprises of assumptions (set of decisions) made by researcher about a problem, methods selected to solve that problem, specific methods and techniques for the data collection, analysis, and interpretation of the results (Abowitz and Toole, 2010). Selection of an appropriate research design also depends on the type of research problem, researcher's expertise, and population of study (Creswell, 2013). This is because each approach has its own inherent advantages and disadvantages, and it depends on the nature of the issue to be dealt with, kind of data to be collected and the conclusions to be drawn. Before making a choice on appropriate research design, different research approaches were explored in order to provide guidance in identifying the most appropriate approach to data collection, analysis, and interpretation of this study.

3.2.1 Research approaches

There are different categories of research. According to Yin (2009), categories based on the purpose of research are: descriptive, exploratory and explanatory. Descriptive research explains characteristics of a phenomenon under consideration; and it does not establish the cause of occurrence of a phenomenon. Exploratory research is a type of research often conducted to explore characteristics of constructs understudy and explanatory studies explain the causal relationship among variables. Categories based on approaches are; quantitative research and qualitative research (Kothari, 2004). This classification concerns with the methods adopted for data collection and analysis (Fellows and Liu, 2008). The approach to be adopted depends on nature of the enquiry which dictates the methods to be used for data collection and analysis. Generally, research can be classified into three main types:

a) Qualitative research - Qualitative research approach is a diverse technique that provides phenomenological investigators with a philosophical basis. Qualitative research is primarily exploratory research. Qualitative research is also used to uncover patterns in thought process and perceptions that provide a deeper understanding of the issue. It highlights the need for a systematic reading and research of textual data that could be an image, written content, or a conversation (Neuman, 1997). Qualitative data collection methods are done using several ways. This type of research involves - questionnaire survey, pilot survey, interviews, observations and case studies. Typically, this method is adopted when the sample size is small and the respondents are carefully selected to perform a specific task.

b) Quantitative research - Origins of quantitative research is with observable facts. Quantitative research is used to quantify the problem with numerical data, and analyzing this data with statistical, mathematical or numerical analysis collected through surveys, observations, etc. and is used to describe and test the relationships between variables. It is used to examine the cause and effect of relationships between the variables. Quantitative research design is an excellent way to finalize findings and testing hypothesis. Quantitative research includes statistical methods to evaluate the relationship between the variables. Moreover, quantitative researchers favor exact measurements and objective research, which checks theory for practical discernment. It is also believed that results may be generalized to the population based on the study sample. This approach supports the use of questionnaire to obtain data, use accurate reliable methods to test hypotheses, and produce representative data (Stiles, 2003). Awodele (2012) concluded that the quantitative method for measuring the behavioral aspect of the built environment was important for confirmatory, explanatory and testing of hypotheses.

c) Mixed-method research - Mixed-method research is increasingly acceptable across various disciplines. This approach incorporates quantitative and qualitative data and is considered as the best way to tackle social science research problems (Johnson et al., 2007; Molina-Azorin, 2012). As reported by Boyd et al., (2005), analyzing research approaches using quantitative and qualitative methods complement one another. Dainty (2008) emphasized that most construction management activities can be seen as

sociological research, that focuses on understanding the dynamics and complex nature of the relationships that form the industry. This study also points out that, dynamic and complex nature of the relationships cannot be better explained adequately by a single methodology. The research work, therefore, adopts mixed methods approach to improve the quality of the results by relying on its inherent advantages. This is because mixed approaches boost the reliability and legitimacy of the outcomes; their validity; and their ingenuity and innovation of the methods (Easterby-Smith et al., 2012). However, this methodology has also been criticized, such as its replicability and significance to address the questions in relation to the research design formulated and this is considered a disadvantage. In the present study, the research design was carefully selected to address these issues.

3.2.2 Sampling techniques and sample design

Due to time and cost limitations, as well as the geographical dispersion of organizations, it would have been impossible to obtain data from all the organizations included in the study population. Sampling was therefore considered to be a representative of the study population. Hence, a sample is regarded to comprise elements that make up the population. Using a sample is much practical and less expensive as compared to retrieving data from the total population. Sampling also indicates the procedure of choosing a portion of the population to stand for the whole population (Kothari, 2004).

The sampling technique considered for this study in relation to the research design, the purpose, and to draw realistic inference of the research topic is purposive sampling. This approach involves a purposeful selection of responses obtained from organizations that constitute the study population. Researcher chooses what needs to be identified and undertakes to locate respondents who are willing to provide information by merit of experience or knowledge (Tongco, 2007). This technique directs the researcher to apply discretion as to who will provide answers, and then purposely request for their viewpoints in the field of study. In situations like this, where the need is to reach a selected sample quickly, this sampling method is very useful.

3.3 SELECTING APPROPRIATE METHODS FOR THIS RESEARCH

Aim of this research is to achieve multiple objectives. In order to assess safety culture, both qualitative and quantitative methods have been used by many researchers. Some studies on safety culture concerning the use of qualitative methods include: interviews and focus group discussions (Cox and Cheyne, 2000), ethnographic studies (Gherardi and Nicolini, 2002; Aboagye-Nimo et al., 2015; Oswald, 2017), discourse analysis (Sherratt et al., 2013) and case studies (Umar and Egbu, 2018).

In this research, both qualitative and quantitative methods will be used consisting of multiple methods such as questionnaires, interviews and case studies. Objective of qualitative analysis was to provide additional insight and an in-depth understanding of study constructs and to triangulate the reported quantitative findings. Additionally, qualitative research should be conducted to analyze the components of cultures of the human factor (Braithwaite et al., 2005; Flin, 2007; Kirk et al., 2007). Qualitative approaches help to investigate safety culture and identify possible strategies (Flin et al., 2006; Perneger, 2006). Moreover, there are very limited studies that use both safety culture surveys and qualitative approaches such as interviews to explain safety culture in industrial settings. Moreover, the primary objective will be done with help of thorough literature review and development of questionnaire survey.

3.3.1 Literature review (Systematic Literature Review)

Literature review is a text of a scholarly paper that encompasses current information, important observations, and theoretical and methodological contributions to a specific subject. Literature review covers scholarly articles, surveys, books and other relevant sources confined to the particular issue and thus offer definition, overview, and critical assessment of these works in relation to the research issue being examined.

A comprehensive review of safety culture articles is undertaken using a 3-step methodology as shown in Figure 3.2. First step intends to collect recent safety culture articles. Then, these articles are codified based on selection criteria that are related to safety culture aspects of construction industry. In the second step, these codified articles are analyzed by descriptive analysis to highlight the recent trends in safety culture research of construction industry. Last step focuses on conducting a systematic literature review to have an overview of safety culture research.

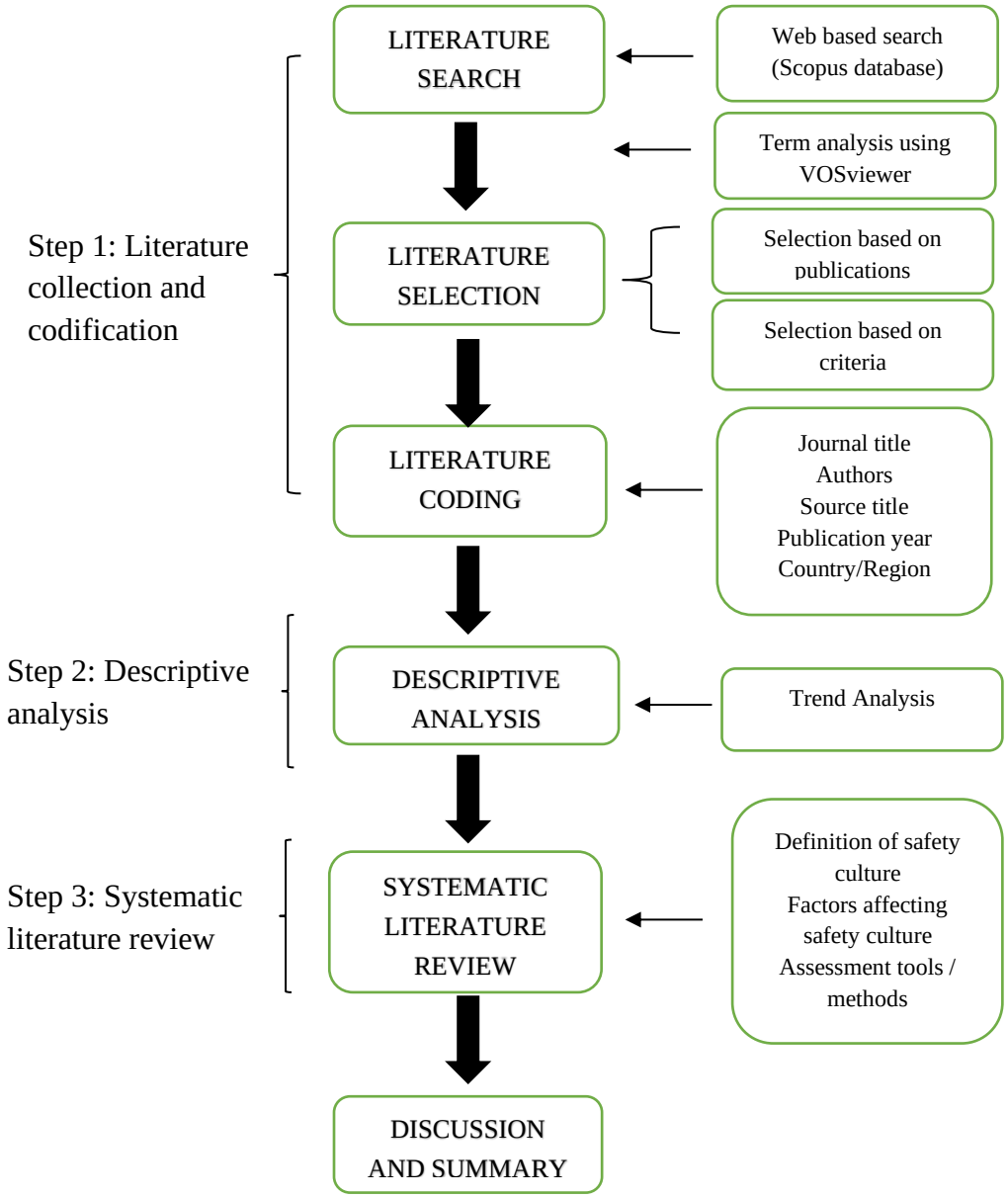


Figure 3.2 Systematic literature review flowchart

3.3.1.1 Literature search

Safety culture articles were collected from web-based search conducted on Scopus database by keywords search for the terms ‘safety culture’ and ‘construction’. The keywords search on ‘safety culture’ and ‘construction’ were made on ‘title’, ‘abstract’ and ‘keywords’ of articles. This search yielded 140 articles and the data of these articles were exported to Microsoft Excel version 2013.

3.3.1.2 Term analysis

Term analysis is established on the data obtained from literature-search method. The analysis of terms that are used in keywords search criteria of articles can offer insight into key topics and trends of safety culture research domain. VOSviewer version 1.6.5 was used to analyze and visualize the terms.

3.3.1.3 Literature selection

140 related articles were obtained based on literature-search method. As this study focuses on safety culture aspects in construction industry, the obtained articles was further scrutinized based on certain criteria that is confined to scope of the study. Since the objective of the review is not focused on gathering sufficient articles, but to provide insight on current trends and issues of safety culture in construction industry, exclusions were made even though they match the subject on safety culture. Exclusion criteria include; i) No direct relevance of the search terms relevant to safety culture in construction industry. The word 'construction' in many cases does not refer to construction industry but used as a 'construct' of an event in general. ii) Only the words matching the criteria were considered for the study. As a result, 51 relevant articles were obtained after exclusions considering above criteria (see Annexure-A).

3.3.1.4 Literature coding

Literature coding was done for the selected articles based on 'title', 'authors', 'source title', 'year of publication' and 'country/region'. When the necessary information is not obtained from literature-search method, then the entire article is assessed to aid coding. Primary focus of article coding was on the articles' distribution by publication, year of publication and country/region-specific (Country/region-specific information was gathered based on actual place of study and not merely the author's country/origin).

3.3.1.5 Systematic literature review

The last step of proposed 3-step methodology is conducting a systematic literature review of existing safety culture research. Primary focus of conducting a systematic literature review is to have a complete overview of safety culture research topic. Systematic literature review is a method for recognizing, choosing, and assessing all literature upon an established level of measurable quality that is suitable to a research problem (Booth et al., 2016). This type of review style is more balanced and consistent

in terms of transparency and objective specific (Jesson, et al., 2011). Hence, a systematic literature review of safety culture articles is conducted.

Systematic literature review limits its focus on construction industry. However, some of the essential papers that focus on safety culture studies were included because of limited theoretical studies being done on construction industry. These studies serve as a new perspective for exploring the commonalities among multiple industries that can be applied to construction industry. Previous systematic literature review limits towards proper identification of research area and knowledge structure. Together, these are considered subjective as they are generally determined by author's decision (Colicchia and Strozzi, 2012; Ngai et al., 2008). Moreover, a study conducted on safety culture by van Nunen et al., (2018) suggested that several efforts are made to develop models and theories in relation to this field, but there is no consensus regarding definition, factors and implying cause and effect of the same. Therefore, the structured systematic literature review modeling as shown in Figure 3.2 overcomes these aforementioned issues and outlines the conception of safety culture in organizations. This majorly covers an overview of; defining safety culture in organizations, conceptualizing various safety culture factors that define these concepts; and lastly, assessment tools for measuring the level of safety culture in organizations.

3.3.2 Questionnaire survey

Surveys are the most widely used means for collecting data in social research (Blaxter et al., 2006). They provide a qualitative or statistical overview of sample that defines the study population based on the trends, attitudes, or opinions of individuals (Creswell, 2009). Broader definition of surveys is given by Saunders et al., (2009) as ‘a research method that involves systematic data collection from a large population’. It was further noted that data collection using questionnaires is often used to describe data when compared to other methods like structured-interviews and case studies. Useful information could be obtained by posing a series of questions about the variables of interest to interested participants in industrial settings. Therefore, it is considered appropriate to gain quantitative information through the traditional quantitative questionnaire approach. This form of questionnaire allows respondents to rate their

responses to a set of questions developed by the researcher on a numerical scale (Creswell and Plano Clark, 2011). In explanatory research, the use of questionnaires helps the researcher to analyze the relationship between variables of interest (Saunders et al., 2009).

Saunders et al., (2009), however, argued that the questionnaire structure varies depending on how it is conducted and how much interaction the researcher has with the respondents. They also point out several ways to administer a questionnaire. In most cases, self-administered questionnaires are completed by the respondents. Blaxter et al., (2006) argued that each of these approaches has its inherent demerits despite the enormous benefits of different methods of questionnaire administration. Face-to-face self-administered questionnaires may have a higher response rate, but it will consume a lot of time for the researcher. Postal and internet-mediated surveys are likely to have lower response levels and probably weaker responses, as the researcher is not available to respond to the concerns of the participants; but these approaches allow for consideration of a larger population (Blaxter et al., 2006).

Current research aims to develop a better understanding of knowledge management strategies that could influence safety culture among employees of construction organizations. In this regard, safety climate questionnaires were considered to perceive how safety culture existed in these organizations. Use of safety climate questionnaire has been the key measurement tool in safety culture research (Guldenmund, 2000). However, Dov, (2008) indicated that the safety climate should be measured at organizational and working group levels as distinct constructs of separate measurement scales, with a view to minimize theoretical uncertainty and distinguishing the disparity between policies and practices at these group levels. In this regard, Flin, (2007) conducted a safety climate survey to evaluate perceptions and attitudes of both worker and patient safety in healthcare sector by dividing safety climate into two groups; that were organization and department/team safety climate.

Previous studies by Bahari and Clarke, (2013) and Zhou et al., (2011) indicated the significance of regional and cultural values of a particular region to be considered in formulating the questionnaire. Pungvongsanuraks et al., (2010) proposed and

implemented a method of investigating the key enablers for safety culture improvement among the two working levels (management and workers). Construction safety culture is developed and established as a mixture and outcomes of the interaction between organization safety cultures of the owner, contractor, and subcontractors at the construction project settings. However, there exists a misalignment between owner's safety culture and project safety culture, which was mainly caused by the weak safety culture of subcontractors (Fang et al., 2012). This issue is closely related to the management practices of construction projects and the organization structure of project teams; but these are usually not addressed in general evaluation of safety culture. Therefore, safety culture survey is suggested to be conducted among major players of the project (i.e., owner, contractor, and subcontractors) so that their specific contributions to safety culture and the interactive relationship between them could be explored.

In safety culture research, questionnaire has been the predominant measurement instrument (Guldenmund, 2000; Gadd and Collins, 2002). Although the usefulness of surveys to expose the core of safety culture is questionable (Antonsen, 2009; Guldenmund, 2010), they are helpful in exposing the attitudes that are shared throughout the whole of the organization (Guldenmund, 2007). However, questionnaire surveys have been widely used to study safety culture because of ease to perform at the least cost expense (Dedobbeleer and Béland, 1991; Mearns et al., 2003; McDonald et al., 2009; Zohar, 2010; Chen and Jin, 2012). In construction sites, assessing safety culture with the use of questionnaires can provide reliable prediction of the level of overall safety culture that seeks improvement in identifying cultural dimensions within the context of organization process and structure (Fang and Wu, 2013). The best way to begin an examination of assessing knowledge-based safety culture is to embrace procedures established in previous studies, with an attempt to adapt it in the Indian context. Earlier studies showed the importance and benefits of knowledge management in improving the safety performance of construction industry.

In this research, a questionnaire survey is developed to gather information and generalize the study about individuals that represents a population or set of people. In the context of this research, the strategy involves identifying professionals involved in

safety management practices being followed on worksites of construction projects. Among them, personnel involved are site engineers, safety officials, project managers and professionals from the top management level. Hence, the present study aims at investigating the process of developing a safety culture questionnaire in the Indian context and methods to assess knowledge-based safety culture which has never been addressed earlier. For this study, a questionnaire survey gathers opinion on important factors in consideration to develop overall safety culture and these data are collected from construction professionals from several parts of the nation.

3.3.3 Case studies and interviews

Case study research approach is based on the fact that case studies can be adjusted to new questions and ideas as they arise (Amaratunga et al., 2002). The nature of the research and availability of multiple sources of evidence makes this approach particularly relevant to the analysis. Proverbs and Gameson, (2008) recognize that case studies are important for construction organizations, where the driving force is multiple projects that are involved in various types of organizations. Therefore, involvement of multiple-case design for collection of qualitative data and its analysis is deemed important (Yin, 2009).

For conducting case studies, data is collected through quantitative assessment framework developed in the study. Later, a semi-structured interview is conducted which includes a list of questions that are put forth to the respondents to get a deeper understanding of the problem and to validate the findings. Data was collected from construction organizations and was documented. Main feature of conducting case study research draws cases from multiple sources of evidence and seeks to provide meaning to the context that clearly helps to understand the issues in-depth and ultimately focuses on the context that the study must be reasonably bounded.

Validity and reliability in qualitative research are done through careful selection of multiple-case scenarios that highlight the focus of the study. A well-defined interview protocol was prepared to show the questions that center on the topic of interest. Internal

validity was enhanced through the use of semi-structured interviews and is compiled to interpret the study findings.

3.4 METHODS OF DATA ANALYSIS

In order to properly handle the data collected from questionnaire survey, it is important for researchers to adopt appropriate data analysis techniques (Ankrah, 2007). In this regard, multiple research methods are employed to improve the reliability and validity of the study results. Quantitative data is analyzed by both descriptive and inferential statistical methods. Descriptive statistics were utilized to analyze the background information; in particular, the demographic profile of the respondents. On the other hand, inferential statistics conducted are; Exploratory Factor Analysis (EFA), Multiple Analysis of Variance (MANOVA) and Confirmatory Factor Analysis (CFA) by Partial Least Square-Structural Equation Modelling (PLS-SEM).

Exploratory Factor Analysis (EFA) - EFA is a statistical method that is used to uncover the underlying structure of relatively large set of factors. EFA is a factor analysis methodology whose primary objective is to define the underlying relationships between measured factors. Factor analysis is a method where values of observed data are used to determine the most important factors in a number of possible causes. This statistical technique is considered adequate for interpreting perception in survey style research and for evaluating the validity of constructs or research tool (Williams et al., 2010). According to Hair et al., (2010), factor analysis is described as a multivariate statistical method to study the basic constructs or interrelationship of the structure within a large number of variables. This is indicated by variables that are highly correlated with each other and thereby forming components or clusters that are intended to contribute to a common structure.

In the analysis, there are generally two methods of characterizing the structure of the variables for creating the factors. They are; Factor Analysis (FA) and Principal Component Analysis (PCA) (Field, 2013). These two methods aim to reduce a large number of variables into a smaller set of dimensions which are termed as ‘factors’ in factor analysis and ‘components’ in Principal Component Analysis. Purpose of Factor

Analysis is to obtain smaller set of uncorrelated variables from a larger set of correlated variables and in order to examine those variables that converge or measure to a particular factor. This method is used for data reduction purpose. Principal Component Analysis is a method used for factor extraction where the derived components from the analysis can be used to calculate a new set of variables for further analyses.

In literature, there has been some debate about the minimum sample size for factor analysis (Mundfrom, et al., 2005; Tabachnick and Fidell, 2007). In this regard, the suggested sample size of 50 is considered reasonable and acceptable (De Winter et al., 2009). This is still considered reliable with sample size of 50 but with a factor loading of 0.75 as suggested by Hair et al. (2010). Also, Field (2013), recommended that a sample size of less than 100 is also acceptable provided the commonality values are greater than 0.60. However, loadings on factors above 0.50 were considered to represent the underlying construct for a sample size of 200 or greater (Hair et al., 2007). Therefore, factor analysis was considered reasonable. Exploratory Factor Analysis is carried out by using Statistical Package for the Social Science (SPSS v22.0) software.

Multiple Analysis of Variance (MANOVA) – This is a technique for checking if two or more population means differ substantially and is ideal for comparing the properties of different constructs (Ankrah, 2007). This technique relies on F-test statistical method to test and compare mean value of the construct underlying the groups that differ substantially (Fellows and Liu, 2008). This test was employed to investigate whether the means of demographic attributes of respondents and their perception of knowledge-based safety culture constructs differed between the groups. In this method, F-ratio is determined and it represents the ratio of variance between the groups to the variance within the group. A higher F value indicates that there is more variability between the groups than within each group. A large F value may indicate that it is necessary to reject the null hypothesis (this suggests that the population group means are equal).

Confirmatory Factor Analysis (CFA) by using Partial Least Square-Structural Equation Modelling (PLS-SEM) - Confirmatory factor analysis is a special form of factor analysis and is used to test whether measures of a construct are consistent with the researcher's understanding of the nature of that construct (or factor). It is done by

formulating a Structural Equation Model (SEM). SEM is a multivariate statistical analysis technique that is used to analyze structural relationships between the variables and is a combination of both factor analysis and multiple regression analysis. This technique was used to develop and validate the conceptual framework which is presented in Section 2.10. SEM is done by SmartPLS (version 2.0.M3) software.

The most important step involved in the process of model development is model validation. Researchers are constantly testing and validating theories and concepts empirically across various disciplines like marketing, health care, psychology, strategic management and this has led to increased use of methods to determine causal relationship by modeling techniques like Structural Equation Modelling (SEM) (Fernandes, 2012; Hair et al., 2012). This technique follows second-generation multivariate analysis that combines variables of the first-generation techniques like Principal Component Analysis and Regression analysis. Furthermore, this technique helps to evaluate causal relationship between variables that are tested based on inherent theories and concepts (Chin, 2010; Robins, 2012).

There are two approaches in SEM; and they are: Covariance-Based Structural Equation Modelling and Variance-Based Partial Least Squares (PLS) path modeling (Hair et al., 2012). Covariance-Based Structural Equation Modelling is a confirmatory technique that is based on estimating relationship between variables constructed on model's theoretical parameters. Partial Least Squares-Structural Equation Modelling (PLS-SEM), on the other hand, is a predictive method that focuses on estimating relationships by expanding the explained variance in the model (Hair et al., 2012). Additionally, PLS-SEM enables to explore defined set of relationships between one or more predictor variables. However, Robins, (2012) stated that PLS-SEM is particularly suitable for strategic management studies as it enables researchers to establish and refine concepts and theories.

PLS-SEM is a multivariate prediction-oriented, variance-based technique that has robust distributional assumptions of normality necessary for maximum likelihood-based SEM estimates (Hair et al., 2012). PLS-SEM is based on a series of Ordinary Least Square regressions that can be used for a smaller sample size (unlike covariance-

based SEM), while at the same time achieving high levels of predictive statistics (Nandakumar, 2008; Reinartz et al., 2009). It is, however, performed using a series of paths or structural equations that simultaneously estimate all direct causal paths and generate overall goodness of fit measures for the model.

PLS-SEM is carried out by using SmartPLS (Version 2.0 (M3)) software. To begin with, PLS-SEM was used to create the path model as shown in Chapter 5 that connects the observed variables and latent variables based on theories and concepts discussed in Chapter 2. The hypothesized knowledge-based safety culture model comprises of 46 factors (termed as observed variables) and five constructs that measure knowledge-based safety culture in construction industry.

3.5 ETHICAL CONSIDERATIONS

Researchers carefully consider ethical validity of the suggested methods when preparing and performing the analysis. Shah (2011) argued that ethics is generally characterized as standard of conduct that distinguishes between acceptable and unacceptable conduct. Ethical considerations employed in this research were seen as part of a system or context used to determine how the analysis was carried out. According to Jimoh (2012), the analysis and its findings will be considered legitimate by researchers that adhere to ethical principles. The researcher ensured at the outset that the respondents were adequately informed about the particulars of the study. Their consent was sought through a letter of participation after seeking requisite permission from the two groups under consideration (see Annexure B) and later followed up with several e-mails. The research was designed in such a way that the details of the participants were kept anonymous and all information provided was kept confidential. Also, the identity of the participants and organizations involved in testing and validation of the assessment framework and interviews analysis conducted was guaranteed with privacy and secrecy. In this regard, information related to participants and their organizations were known only by the researcher and research supervisor.

3.6 RESEARCH METHODS IN RELATION TO OBJECTIVES

- The study was started with a systematic literature review of recent trends and researches of safety culture in construction organization. In this regard, contributary factors required to assess and improve safety culture in construction organizations are identified. Most suitable method for identifying key factors is: literature review, questionnaire survey, and case studies. Firstly, a detailed and thorough literature review was done to identify the contributary factors. The factors used for the study were extracted from both within and outside the research literature on construction management; in developing the layout of the questionnaire. These factors are established for evaluating the importance of reducing the accident rates and understanding the importance of knowledge management strategies that can improve safety culture in construction industry.
- The second objective of the study is to assess the suitability of the identified factors in each of knowledge-based safety culture dimensions including the neglected knowledge dimension. This is done by developing a survey instrument. Initially, a pilot study is carried out to know the relevance of the identified factors developed from the survey instrument. Pilot study is carried out to check the clarity and comprehensiveness of the questions formulated for the survey. Survey instrument was then administered for main study among the defined sampling frame considered for the study. Data obtained from survey responses were quantitatively analyzed to: i) identify the significant and most influencing knowledge-based safety culture factors in construction organizations, ii) evaluate the degree of interdependency of the identified factors. Quantitative analysis is done with the use of Statistical Package for the Social Science (SPSS v22.0) and SmartPLS (version 2.0.M3) software. Statistical methods carried out include: Factor Analysis (FA), Multiple Analysis of Variance (MANOVA) and Partial Least Square-Structural Equation Modelling (PLS-SEM).
- Finally, based on the results obtained from the quantitative analysis, an assessment framework is formulated. This assessment framework was tested with different case scenarios that are considered to evaluate and test whether knowledge-based safety culture factors could improve safety performance in construction organizations. Lastly, based on the results of the interview, an improvement

framework is proposed that is required to suggest improvement in safety culture practices among construction organizations.

3.7 CHAPTER SUMMARY

This chapter discussed the methods used for data collection its analysis as well as explained the methodological rationale for the study. Firstly, a detailed procedure of conducting systematic literature review is explained to uncover the recent trends and overview of safety culture research in construction industry. Next, the data collected through the use of questionnaire survey; assessment of framework through case studies and interviews are discussed in detail. This chapter explicitly explains the use of mixed-method approach considered for the study. Next chapter presents the design and development of questionnaire survey instrument, as well as discussion of its application.

CHAPTER 4

QUESTIONNAIRE INSTRUMENT DESIGN

The focus of this chapter is to present the development of questionnaire instrument in achieving the objectives and providing justifications for the same. In this regard, this chapter outlines the design and administration of questionnaire survey adopted in the study.

4.1 SURVEY DESIGN AND ADMINISTRATION

A questionnaire survey is employed as an effective instrument to collect the data for the study. The formulation of a questionnaire survey is based on the identified factors from review of literature. Safety culture factors were considered as the basis for designing the survey instrument. This section explains the very purpose of necessitating a survey and highlights the outline of the survey adopted.

Questionnaire survey is a measuring instrument used for data collection of large samples in a survey type of research (Srinivasan and Lohith, 2017). The questionnaire survey is developed to gather information and generalize the study about individuals that represents a population or set of people. In the context of this research, the questionnaire survey is formulated for evaluating factors that focus on improving the safety culture in construction industry that are identified from a thorough literature review. Further, the survey is administered to working professionals involved in safety management practices that are being followed on worksites of construction projects. Among them, personnel involved are: site engineers, safety officials, project managers and other professionals from top and middle management levels. This is because the safety culture factors identified are more concerned and attributed to top-down organizational approach where the focus is on working professionals operating from top and middle management levels of the organizational hierarchy.

4.2 PILOT STUDY

4.2.1 Purpose of pilot study

Initially, a pilot study is done as they are imitation and trail of the main study. The aim of a pilot study is to determine whether there is any defect in the measuring instrument and to minimize the errors in the questionnaire (Kothari, 2004). Questionnaire survey is the tool of measurement which is used in the present research. The sensitivity and applicability of the survey instrument are evaluated through a pilot study to verify the issues regarding the clarity and comprehensiveness of the questions formulated for the survey. Moreover, pilot study was conducted to screen, validate and improve the measurable safety culture factors.

4.2.2 Pilot study administration

Firstly, the questionnaire is subjected to pre-testing, which is done by research supervisor and research scholars. This is done in order to check the effectiveness of the questions or statements that are formulated for the survey. The suggestions provided during pre-testing were then incorporated and modified for the pilot study. Next, in consideration to this, the questionnaire is administered to construction industry professionals through online survey forms. These responses were then captured, analyzed and modified for the main survey.

4.2.3 Pilot study responses

A total of 20 questionnaires were circulated for the pilot study; among them, 11 responses were returned which represents a response rate of 55%. Among them, five valid responses were considered for further analysis; based on certain criteria such as, respondent's designation, years of experience, and the type of organization. Out of these valid responses, two were from main contractors, one each of client and academia, and two were from consultants. Professionals from these responses were mainly project managers, project engineers, and design engineers. These professionals had relevant experience in construction works for providing adequate information required to improve the questionnaire for main survey.

4.2.4 Impact of pilot study responses on main survey

Pilot study was conducted to seek opinion from industry professionals on the development of measuring instrument. Questionnaire survey is employed as a

measuring instrument to assess the relevance of the identified factors from literature review. This instrument is validated by conducting a pilot study of relatively small sample which includes responses from industry professionals (i.e., clients, contractors, consultants, academicians, etc.).

The average time needed to finish the questionnaire was around 30-35 minutes based on the feedback from pilot study participants. Consequently, removal of some of the key statements in the questionnaire was regarded as unnecessary because of its importance to the study. Also, some of the statements were re-worded and were provided with suitable examples for better understanding of the questions or statements. The result of the pilot study revealed that the set of factors under consideration cover the extent towards development of safety culture in construction industry, as some of these factors were also valid in other sectors (manufacturing, hospitality, mining, and others). Only those factors that match the relevant criteria were regarded as valid for developing the survey instrument. Having satisfied the requirement of pilot testing, suitable modifications were done to revise the survey instrument and it was then considered suitable for testing to a larger sample and further tested for main study.

4.3 MAIN STUDY

The design of the questionnaire mainly focuses on the factors that are identified from literature review. The questionnaire also comprised of a brief overview regarding the objective, scope and purpose of the study along with the request for participation. The questionnaire majorly covers two sections.

First part of the questionnaire covers basic information regarding personal attributes of the respondents and includes details about the current working organization. Information in this section includes respondent's company name, work designation, professional experience, organization type, organization size and OHSAS 18001:2007 certification credentials of the organization.

Second part of questionnaire highlights the factors that influence safety culture aspects in construction organizations. These factors are categorized under the dimensions of safety culture, viz. psychological aspects, behavioural aspects, organizational aspects,

and knowledge management aspects. From literature review, factors that influence safety culture are covered in these aspects and for each factor, a statement that defines the measurable factor is specified; for which the survey respondents have to indicate the level of importance that is relevant to their organization. Table 4.1 shows the number of factors covered in each dimension under consideration.

Table 4.1 Number of safety culture factors

Dimensions	Number of factors
Psychological aspects	14
Behavioural aspects	16
Organizational aspects	23
Knowledge management aspects	16
Total	69

The data from the survey is collected using Likert scale ratings. Each of the identified factors is defined by a statement that has a rating scale from 1-5 (1=not important; 2=of little importance; 3=moderately important; 4=important; 5=very important). The questionnaire survey has been developed in the manner that clearly measures safety culture aspects in the construction industry. The factors chosen to develop the questionnaire survey clearly depict the concept of safety culture in a construction industry. This has been further verified by conducting a pilot study.

The main study comprises of attaining the responses through a questionnaire developed after modifying it based on the suggestions provided in the pilot study. Questionnaire survey used for data collection is shown in Annexure-C.

4.3.1 Data collection for main study

After identification of safety culture factors and developing the survey instrument, the next step was selection of the sample for collecting the data. In India, most of the construction companies functioning are recognized with numerous government organizations or some other autonomous organizations established under Indian government regulation. Sample size for distribution of questionnaire was considered from two different groups.

First group consists of members of the Confederation of Real Estate Developers Association of India (CREDAI) operational in Karnataka region. Members of CREDAI are real-estate professionals and developers and are involved in residential type of construction activities. CREDAI-Karnataka region is considered as the study population with focus on company types as clients or owners. CREDAI-Karnataka has different groups based on the location of work; and are termed as CREDAI-Karnataka chapters. Totally, there are ten chapters in this region. The number of working organizations in each chapter is given in Table 4.2.

The second group consists of members of the Construction Industry Council of India (CIDC), New Delhi. The members of this council are generally government organizations and contractors involved in building, industrial, and infrastructure projects across the nation. Totally, there are 117 registered members of CIDC, India. These registered organizations are large and self-performing with well-established safety management systems. Also, these organizations regularly organize training programs, safety meetings, evaluations, etc., wherein all project stakeholders in these organizations are actively connected with these events. Hence, active members of CIDC-India and CREDAI-Karnataka group are considered for the main study.

Table 4.2 List of chapters in CREDAI-Karnataka region

Chapter name	**Number of organizations**
CREDAI - Belagavi	35
CREDAI - Bengaluru	209
CREDAI - Bidar	15
CREDAI - Bijapur	07
CREDAI - Hubli-Dharwad	55
CREDAI - Kalburgi	20
CREDAI - Karwar	13
CREDAI - Mangaluru	62
CREDAI - Mysuru	26
CREDAI - Udupi	33

Total	475

4.3.2 Sampling method

The consideration of sample size is important as it underpins the strength, reliability, and prediction of the hypothesized model based on the proposed theory (Zahoor, 2016). However, it is observed that only 10% of the samples could be a better predictor of accurate results and the sample size of the study should be equal to or more than two times the number of observed variables in the study (Lingard and Rowlinson, 1997). Sampling of the questionnaire is essential as it affects the evaluation and results of the research considerably. A sample should, therefore, be regarded as a good demographic representation of the study population. In this context, it is rather hard, in particular, because of time and practical limitations to collect survey responses for all ongoing construction projects in Indian construction industry. Hence, the data is collected from sampling frame of the two groups under consideration (CIDC- India, and CREDAI-Karnataka).

The minimum sample size adopted for this study is calculated using the following formula (Tripathi and Jha, 2017):

$$ss = \frac{f'}{(1 + \frac{f'}{S})}$$

where,

$$f' = \frac{p \times q}{V^2}$$

where,

ss is minimum sample size;

S is population size considered for the study;

f' is the first estimate of sample size;

p = probability of the proportion of the sampling population.

This study has considered 0.5 as the value of 'p' and 'q' and this was considered to achieve the maximum sample size. Also, the value of the standard error was considered 5% (Hair et al., 2007; Ankrah, 2007; Oyewobi, 2014; Tripathi and Jha, 2017). Using

this formula, the minimum sample size from two groups under consideration is as shown:

S = 117 (CIDC) + 475 (CREDAI) = 592 members

$$f' = \frac{0.5 \times 0.5}{(0.05)^2} = 100$$

$$ss = \frac{100}{(1 + \frac{100}{592})} = 85.55 \approx 86$$

Target respondents for the questionnaire were construction industry professionals and experts. Among them, the focus was on professionals from clients/owners, contractors, sub-contractors, consultants, and others, who had at least two years' experience in execution works of construction projects and this was to guarantee that the responses obtained, are reliable. This research was intended to gather at least 2-3 responses from each organization to minimize common method variance. In this way, the data was collected for the main study based on the sampling frame as explained in this section.

4.4 DATA COLLECTION FOR MAIN STUDY

In line with the sampling method considered for main study, the questionnaire responses were collected. A total of 230 responses were obtained from 110 organizations with a response rate of 51.68 %. The number of organizations obtained (i.e. 110 organizations) is greater than the minimum sample size (i.e. 86 organizations as calculated using minimum sample size provided in section 4.3.2). Among these responses, 20 invalid responses were removed as they were not matching the required criteria (criteria such as the experience of the professional and the type of the stakeholder). Hence, the remaining 210 valid responses were utilized for further analysis. Detailed demographics of the survey respondents are shown in Table 4.3.

Table 4.3: Demographics of the study sample

Variables	Category	Frequency	Percentage (%)
Gender	Male	193	91.9
	Female	17	8.1
Years of experience	Less than 10 years	100	47.6
	10 to 20 years	49	23.3
	20 to 30 years	43	20.5
	Greater than 30 years	18	8.6
Organization type	Client/Owner	151	71.9
	Main contractor	43	20.5
	Consultant	5	2.4
	Others (Government, Academia, etc.)	11	5.2
Size of the organization	Small (Less than 200 employees)	98	46.7
	Medium (200-500 employees)	11	5.2
	Large (More than 500 employees)	101	48.1
OHSAS 18001:2007 certified organization?	Yes	95	45.2
	No	115	54.8

The demographic profile of the respondents is analyzed to present the distribution of the number of respondents based on the several categories (first part of the questionnaire) and is as shown in Figure 4.1.

Amongst the 210 valid responses considered for the study, 151 (71.9%) responses were of clients/owners, 43 (20.5%) responses were of main contractors, 5 (2.4%) responses were consultants and remaining 11 (5.2%) responses accounted for others (government bodies, academia, etc.). Based on the data collected for the main survey, majority of the respondents were clients or owners. This is because, the clients or owners have their own construction wings, i.e. in-house construction groups; and, they hold a proactive role that can significantly influence safety management practices at construction projects. Moreover, clients or owners are believed to influence the perception of safety among working individuals and their behavior to contribute in motivating other stakeholders (Wu et al., 2015).

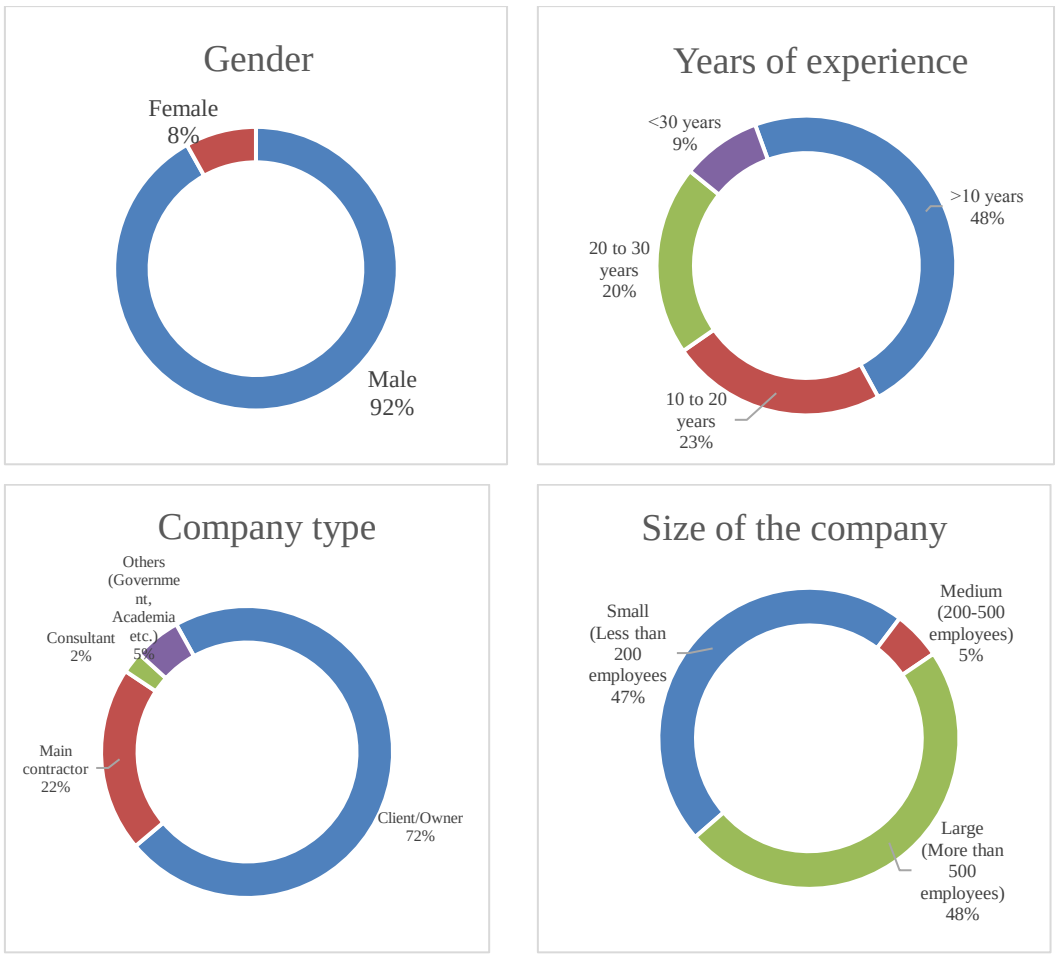


Figure 4.1 Demographic profile of survey respondents

In comparison to clients and contractors, respondent's group of consultants was small; this is because most of the clients and contractors deploy their own team of consultants for the projects. Out of the total responses utilized for this study (i.e. 210 responses), 100 (47.6%) respondents had less than ten years of experience, 49 (23.3%) respondents had ten to twenty years of experience, 43 (20.5%) respondents had twenty to thirty years of experience, and remaining 18 (8.6%) respondents had more than thirty years of experience. The years of experience of all respondents had a mean of 13.47 and a standard deviation of 10.07. Regarding the size of the organization, respondents accounting for small-sized companies were 98 (46.7%), medium-sized companies were 11 (5.2%), and large-sized companies were 101 (48.1%). Further, the number of OHSAS 18001:2007 certified organizations was 95 (45.2%) and non-certified organizations were 115 (54.8%). Hence, it can be summarized that the data obtained

from the survey represented all types of experience levels, types of organizations, different sizes of organizations and OHSAS 18001:2007 certificate credentials.

4.5 CHAPTER SUMMARY

This chapter has described and explained the formulation of the questionnaire survey adopted for this study. Pre-testing and pilot study results for the survey instrument are highlighted. Based on suggestions provided in the pilot study, suitable modifications were done to facilitate the main study. Data collection was based on the sample size consideration adopted for this study. Lastly, the demographic profile of the survey respondents was analyzed and discussed.

CHAPTER 5

INSTRUMENT FOR ASSESSING KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION ORGANIZATIONS

5.1 INTRODUCTION

The current chapter presents the results of the analysis and discussions pertaining to second objective of the study i.e., to assess the relevance of the identified safety culture factors and evaluate the degree of their interdependency. In this regard, the identified safety culture factors are assessed by conducting a questionnaire-based survey. The questionnaire survey responses collected for this study were analyzed to assess the measuring instrument and the underlying factors. This is done by determining the reliability and validity of measurement scale. Reliability of the measurement scale was checked by computing Cronbach's alpha (α) coefficient. Validity of the measurement scale is done by conducting Exploratory Factor Analysis (EFA). Further, to test and validate the hypothesized knowledge-based safety culture constructs and to validate the factor structure obtained from EFA, Confirmatory Factor Analysis (CFA) is performed.

5.2 RELIABILITY AND VALIDITY OF THE MEASUREMENT SCALE

Reliability and validity assessment of measurement scale is done to assess the individual factors of the measuring instrument.

Reliability tests: Reliability tests ensure consistency, reproducibility, and stability of the measurement scale (Li and Tong, 2019). Reliability of measurement scale was checked for internal consistency among the measurable factors. Internal reliability was performed among these measurable factors to examine whether the questionnaire measures a set of questions on the same concept of interest (Li and Tong, 2019). This was checked by computing Cronbach's alpha (α) coefficient and Spearman-Brown coefficient. Cronbach's alpha (α) coefficient represents the mean correlation among factors and Spearman-Brown coefficient value represents the correlation of the factors which is obtained by splitting the data into two sets. The cut-off value for these

coefficients is 0.70 indicating reliable data sets to perform the study (Nunnally and Bernstein, 1994; Hair et al., 2007). These coefficients are generally considered as the index of the measurement of reliability and are used to represent the consistency of the measured items and to assess the internal well-formedness of the measurement scale (Li and Tong, 2019).

Validity tests: Validity is the degree to which an instrument truly measures the concept of interest (Hair et al., 2007). Also, the prevalent validity test techniques differ for the distinct measurement outcomes and outcomes needed to meet the research objectives. In general, there are three types of validity: (i) Content validity, (ii) Construct validity, (iii) Discriminant validity. Content validity of the measurable factors that were identified and grouped under four dimensions was established by conducting a thorough review of literature and was confirmed through the pilot study. This establishes that all factors which intend to represent the underlying dimensions were validated by content validity. Construct validity of the factors was tested by Exploratory Factor Analysis (EFA). In construct validity, Kaiser-Meyer-Olkin (KMO) test was used for checking the sampling adequacy and Bartlett's Test of Sphericity is used for assessing correlations among measuring factors. Discriminant validity was checked by Multiple Analysis of Variances (MANOVA) for various factors against demographic profile of the survey respondents.

5.3 RELIABILITY TEST OF THE MEASUREMENT SCALE

Reliability of the measurement scale was assessed by both Cronbach's alpha (α) coefficient and Spearman-Brown coefficient. Results indicate that both Cronbach's alpha (α) coefficient and Spearman-Brown coefficient was greater than 0.90 for all constructs. A coefficient value greater than 0.90 (Hair et al., 2007) signifies adequate requirement for psychometric properties of measurement scale and in this case, it is suitable for measuring knowledge-based safety culture. Among the safety culture constructs, the lowest and highest scores were obtained for psychological dimension (3.62±0.81) and knowledge dimension (3.77±0.78) respectively. A mean score of a dimension greater than 3.00 would show consistency among individuals perception and indicate the importance of safety culture factors; and similarly, a mean score less than

3.00 would imply weak perception of individuals concerning the importance of safety culture factors. Also, mean value of the dimension represents the respondent's opinion, and with the higher scores indicating a higher degree of importance, and smaller standard deviations value indicate higher consistency of opinion based around the set of factors. Table 5.1 shows descriptive statistics for all knowledge-based safety culture constructs.

Table 5.1 Descriptive statistics of knowledge-based safety culture constructs

Constructs / Dimensions	Number of factors	Mean (M)	Standard deviation (SD)	Cronbach's alpha coefficient	Spearman-Brown coefficient
Psychological dimension	14	3.62	0.81	0.96	0.96
Behavioural dimension	16	3.64	0.82	0.97	0.97
Organizational dimension	23	3.67	0.78	0.98	0.99
Knowledge dimension	16	3.77	0.78	0.97	0.98

Descriptive statistics results indicate that the knowledge dimension turns out to have a significant impact in comparison to other dimensions. This shows that the measure of knowledge-based safety culture is necessary.

5.4 VALIDITY TEST OF THE MEASUREMENT SCALE

Validity of the measurement scale is determined by testing of construct validity of the factors and then checked for discriminant validity by conducting Multiple Analysis of Variance (MANOVA) test.

5.4.1 Exploratory factor analysis

The survey responses were utilized for evaluating construct validity by performing exploratory factor analysis. Factor analysis was done in order to determine the relevance of each factor under safety culture dimensions. This analysis is a data reduction technique that works to quantify the correlation between different factors under a construct (principal components) and thus removes factors that are unrelated to

each other. This will enable the examination to be centered on the key constructs and understanding the nature and dynamics of their correlation. Generally, to conduct factor analysis, a sample size of more than 100 responses is essential or to have a minimum number of data sets greater than or equal to four to five times the number of factors per construct (Hair et al., 2007). This study has a sample size of 210 responses and is therefore considered adequate to meet the statistical requirements to perform exploratory factor analysis.

Appropriateness and suitability of data to perform EFA was analyzed by Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity tests. Analysis showed that KMO value of 0.956 is greater than 0.90, indicating that this data was appropriate for conducting factor analysis. In Bartlett's Test of Sphericity, the significance value is less than 0.05 (Shi et al., 2014) signifying that correlations existed among safety culture factors. Also, values were found to be significant for all four constructs indicating that correlations occurred among factors in their respective constructs. Therefore, the data were found to be appropriate for the conduct of exploratory factor analysis. Detailed values of these test results are presented in Table 5.2.

Table 5.2 KMO and Bartlett's Test

KMO Measure of Sampling Adequacy.	0.956
Bartlett's Test of Sphericity: Approximate Chi-Square value	17732.955
df (degree of freedom)	2346
Sig. (significance value)	0.000

The results of the exploratory factor analysis show the loadings of the factors on their respective constructs, the communality values, and Cronbach's alpha (α) coefficient. Loadings on factors above 0.50 were considered to represent the underlying construct for a sample size of 200 or greater (Hair et al., 2007) and this is essential to weed out factors with low loadings. Principal component analysis was the method utilized to extract the constructs during the analysis. Principal component extraction of factors under four constructs is shown in Table 5.3. The extraction method resulted in twelve components having an Eigenvalue greater than 1. However, some of the factors had low factor loadings (lesser than 0.50) and cross-loadings of factors were observed on

the components they intend to represent. These factors were not considered and were removed from further analysis. Further, the extraction method was repeated considering the fixed number of components (i.e. five) instead of Eigenvalue greater than 1. The rotation method adopted for obtaining factor structure was Oblimin method with Kaiser normalization and this is based on the correlation existing between the components (greater than 0.32) obtained from component correlation matrix (Zahoor, 2016). Results of the factor analysis indicated that psychological, behavioural and knowledge dimensions yielded a single component and organizational dimension yielded two components. These five components intend to signify the overall condition of safety culture dimensions and give a sensible explanation of safety culture structure in construction industry. Careful analysis of the factors based on factor loadings and cross-loadings in each of the components yielded 46 factors that were retained out of a total of 69 identified factors. Results of the factor analysis comprising of 46-factor pattern matrix with five components are shown in Table 5.3.

Table 5.3 Factor structure of knowledge-based safety culture constructs

Factors	Statement	Factor loadings	Communalities	Cronbach's alpha (α)
B – Behavioural dimension (Eigen value = 40.806; Percentage of Variance = 59.139; Cumulative percentage of variance = 59.139)				
B13	Modeling safe work practices in the job	0.647	0.778	0.915
B1	Personal responsibility to safety actions	0.562	0.783	
B9	Time and contacts for safety knowledge sharing	0.512	0.821	
K – Knowledge dimension (Eigen value = 2.841; Percentage of Variance = 4.117; Cumulative percentage of variance = 63.256)				
K15	Intuition and synthesis of safety facts and to apply them when necessary	0.784	0.739	
K7	Comprehensive occupational health and safety policy	0.763	0.718	
K13	Physical experience of an individual/group towards safety	0.753	0.714	

K4	Essential requirement of company records that conform with safety policies of the organization	0.728	0.721	0.968
K11	Relatedness towards practical aspects of safety	0.718	0.749	
K6	Accident analysis and self-inspections at job	0.697	0.744	
K8	Presence of integrated safety documentation system	0.688	0.764	
K12	Perceptual and cognitive skills to work safely	0.682	0.777	
K10	Safety hazard recognition and to take corrective actions	0.668	0.743	
K16	Ability to learn and share values	0.663	0.736	
K3	Following safety guidelines (rules and regulations) that comply with safety standards	0.663	0.780	
K14	Clear understanding of thumb rules about safety	0.640	0.771	
K2	Safety regulations to prevent accidents/ incidents at work	0.639	0.790	
K9	Safety engineer's experience contributes to work safely	0.638	0.750	
K1	Maintaining accidents records for analyzing the type and severity of accident occurring at the workplace	0.636	0.753	
K5	Availability of safety databases in the organization	0.610	0.726	
O_1 – Organization safety practices dimension (Eigen value = 2.118; Percentage of Variance = 3.069; Cumulative percentage of variance = 66.325)				
O7	Being in accordance with safety compliance	0.600	0.764	0.925
O19	Organization Safety-knowledge effectiveness	0.553	0.780	
O11	Availability of Communities of Practice to handle safety problems at organization	0.541	0.771	

O23	Ease of access and retrieval of stored safety knowledge using database management tools	0.500	0.770	
P – Psychological dimension (Eigen value = 1.674; Percentage of Variance = 2.426; Cumulative percentage of variance = 68.751)				
P1	Personal commitment	0.865	0.689	0.959
P7	Personality and willingness to share safety knowledge	0.770	0.743	
P13	Occupational Health & Safety expertise (OH&S) expertise influence on workplace safety	0.756	0.773	
P10	Employee recognition for adhering to safety rules and regulations	0.755	0.742	
P2	Job satisfaction	0.746	0.744	
P14	Safety mentoring process	0.746	0.774	
P11	Involvement in or exposure to safety-related issues fosters physical experience	0.745	0.721	
P5	Adaptability to new systems	0.738	0.748	
P4	Culture, language, and background of an individual	0.694	0.687	
P3	Relationship among co-workers	0.666	0.718	
P8	Safety knowledge and training competence of employees	0.662	0.751	
P6	Employee compliance towards safety standards	0.608	0.771	
P12	Participation/Involvement in safety-performance evaluation	0.586	0.734	
P9	Financial incentives are provided for safety knowledge sharing process	0.558	0.672	
O_2 – Organization policies, rules and regulations dimension (Eigen value = 1.417; Percentage of Variance = 2.054; Cumulative percentage of variance = 70.805)				

O16	Formalized process for storing safety knowledge	0.664	0.753	0.957
O10	Proper communication and feedback mechanism on safety issues	0.652	0.794	
O14	Regular discussion / meetings related to safety	0.607	0.781	
O8	Structured and systematic approach to managing conflict	0.603	0.792	
O22	Proper investment and budgetary requirements for effective safety knowledge management implementation	0.603	0.806	
O20	Effective in storing safety matters in organizational memory and build safety knowledge management system	0.586	0.830	
O4	Influence of leadership towards safety concerns at projects	0.570	0.799	
O2	Well-established Information Technology and Human Resource Management that complies with positive safety culture	0.532	0.752	
O12	Safety planning implementation to prevent accidents/incidents occurring at the job site	0.503	0.831	

The five-factor solution explained a total variance of 70.805%. The percentage of variance explained by the components B, K, O_1, P and O_2 are 59.139%, 4.117%, 3.069%, 2.426% and 2.054% respectively. Eigenvalues of all the five constructs were more than minimum required value of 1. Based on the analysis, factor loadings under each construct were greater than 0.50, indicating that the variance in each of the factors is sufficiently explained by the respective construct and is therefore considered significant (Hair et al., 2007). Also, communality values are high (>0.60), signifying

that a larger amount of variance in the factor has been extracted for obtaining the factor solution (Preacher and MacCallum, 2002).

The extracted five constructs along with their factors are:

(i) B: Behavioural dimension. This component consists of three factors, B13, B1 and B9 which mainly focus on behavioural aspects of safety culture including the importance of modelling safe work practices at the job site, personal responsibility to safety actions and appropriate time and contacts for safety knowledge sharing in the organization.

(ii) K: Knowledge dimension. There were 16 factors included in this component of safety culture (K1 to K14). Factors in this component mainly focus on the importance of knowledge management strategies related to safety culture aspects in the construction industry.

(iii) O_1: Organization safety practices dimension. Most of the factors in this component attribute to organization safety practices. Factors included in this component are O7, O19, O11, and O23.

(iv) P: Psychological dimension. All 14 psychological factors were included in this component (P1 to P14). Factors in this component mainly focus on the importance of an individual's personal influence on safety such as commitment, personality, satisfaction, involvement in safety management process, etc.

(v) O_2: Organization policies, rules and regulations dimension. This component consists of ten factors (O2, O4, O8, O10, O12, O14, O16, O20, and O22). This component mainly focuses on organization policies, rules, and regulations.

Cronbach's alpha (α) coefficient for all the extracted components ranged from 0.915 to 0.968, which were greater than the cut-off value of 0.90 and thus indicating reasonable reliability of the component structure (Hair et al., 2007). Results of the factor analysis indicate each of the factors that have sufficient factor loadings on the underlying construct shows significant effect in explaining the influence of knowledge-based safety culture in construction industry. Results of the exploratory factor analysis indicate that there exists definite correlation between these five components (B, K, O_1,

P and O_2), and exhibiting a causal relationship among these components will provide a foundation or theoretical modeling.

5.4.2 Multiple Analysis of Variance (MANOVA)

Discriminant validity of knowledge-based safety culture constructs: This validity test aims to inspect whether there is any significant difference in the resulted constructs of factor analysis with the demographic groups of survey respondents. The constructs derived from factor analysis that primarily agree on the effect of overall safety culture in construction industry are gender, years of experience, organization type and size, and lastly safety certification credentials of the organization. In doing so, the distinction of demographic profile is divided based on gender (male and female), years of experience (less than 10 years, 10 to 20 years, 20 to 30 years, greater than 30 years), type of organization (client/owner, main contractor, consultant and others), size of organization (small, medium and large) and OSHAS 18001:2007 certified and non-certified organizations as shown in Table 5.4. Results of the analysis indicate that there is no significant difference among different constructs based on gender. However, there are significant differences in organization type, size and certification credentials. This means that there exists a difference in perception of knowledge-based safety culture constructs among individuals belonging to different type of organization (client/owner, main contractor, consultant and others), and size of organization (small, medium and large), and lastly individuals from 18001:2007 certified and non-certified organizations.

Results of discriminant validity test suggest that there was a significant difference detected among few parameters on the factor structure of the constructs. However, if there exists any significance among these factors, then the whole dimension is considered significant to that particular demographic profile (Agumba and Haupt, 2014). Demographic profile of the respondents has no statistically significant difference in terms of their gender and total job experience in their current workplace. This is in agreement with the study conducted by Akdeniz et al., (2018) on perceiving safety culture perceptions in organizations. Although, experience of an individual plays an important role in assessing safety culture at the workplace, yet some safety culture constructs showed no statistically significant difference based on their perception.

Table 5.4 Discriminant validity of knowledge-based safety culture constructs

Demographic profile of the respondents	Significance	P	B	O_1	O_2	K
Gender	F	0.247	0.004	1.424	1.349	1.432
	p	ns	ns	ns	ns	ns
Years of experience	F	3.671	2.304	3.583	0.661	0.873
	p	0.013	ns	0.015	ns	ns
Company type	F	3.882	7.470	5.746	3.362	4.268
	p	ns	<0.05	0.001	0.020	0.005
Company size	F	11.557	15.615	5.773	8.382	6.916
	p	<0.05	<0.05	0.004	<0.05	<0.05
OSHAS certified company	F	20.511	30.569	10.862	16.732	14.146
	p	<0.05	<0.05	0.001	<0.05	<0.05

Note: F: F-value; p: probability value; P: Psychological dimension; B: Behavioural dimension; O_1: Organization safety practices dimension; O_2: Organization safety policies, rules and regulations dimension; K: Knowledge dimension

Further, a very important observation is the difference in perception based on size, type and OHSAS 18001:2007 certified and non-certified organizations. This is because organizations of larger size (employee size greater than 500) and having certification credentials to their organization will be able to operate efficiently on their organization's health and safety management aspects supported by organization's policies, standards, rules and regulations (Paas et al., 2015). Also, there is a strong and positive perception among employees in these organizations towards safety attitude, safety involvement, safety promotions, policies and suitable work environment for safety-knowledge sharing mechanisms (Saedi et al., 2019).

The differences in knowledge-based safety culture dimensions on various categories of demographic profile of the respondents aim to identify the potential categories that require special and significant attention for improving safety culture among several organizations in construction industry. As a matter of fact, differences in operations and duties among organization's employees can be linked to the contribution of differing demographic characteristics on factors related to safety culture.

5.5 CAUSAL RELATIONSHIP OF KNOWLEDGE-BASED SAFETY CULTURE DIMENSIONS

In this section, the focus is on determining the causal relationship of knowledge-based safety culture dimensions on overall safety culture of the construction industry. This is done to evaluate the degree of interdependency of the identified factors under each of knowledge-based safety culture dimensions. In this regard, the five-component structure derived from exploratory factor analysis was validated by confirmatory factor analysis (CFA). Smart Partial Least Square (SmartPLS v2.0.M3) was utilized to analyze the causal relationship of factors underlying knowledge-based safety culture constructs.

5.5.1 Partial least square (PLS-SEM Approach)

Partial least square (PLS) is a variance-based technique used in several areas of construction management (Gunduz et al., 2016; Durdyev et al., 2018). PLS has been used for specifying the causal relationship between observed and latent variables and it is in due consideration of exploratory nature of this study (Gefen, et al., 2000). Also, this technique helps to analyze multiple dependent and independent variables simultaneously. The choice of adopting PLS method for this research is to determine the predictive ability of the independent variables (i.e. knowledge-based safety culture variables) on the outcome variables (overall safety culture). Further, the ability to test and validate the influence of knowledge-based safety culture variables on improving the overall safety culture in construction industry is made possible. The use of SmartPLS (v2.0.M3) path analysis technique was found to be suitable because of the following reasons:

- The hypothesis proposed for this study could be tested in a single path diagram.
- The technique has less impact with respect to sampling size and its distribution (Chin, 1998). The problem of large sample size (greater than 200) utilized for the study could provide reliable estimates of the outcome.
- Factor structure of constructs obtained from factor analysis does not exhibit multicollinearity.

PLS-SEM path modeling was considered appropriate to analyze the measurement and structural models in the study. PLS-SEM model comprises of two types of variables i.e. observed variables (directly measured variables) and latent variables (theoretical

constructs or hypothetical constructs obtained from measured variables) (Hensler, 2009). The hypothesized knowledge-based safety culture model comprised of 46 factors (termed as observed variables) and five constructs that measure knowledge-based safety culture. The proposed factor structure was in line with literature consisting of both measurement model and structural model (Gunduz et al., 2016; Durdyev et al., 2018). The measurement model provides the relationship between each knowledge-based safety culture factors (i.e. observed variables) and its respective construct (i.e. latent variables), and the structural model provides the association among knowledge-based safety culture dimensions (i.e. first-order latent variables). Further, the second-order latent variable (i.e. measure of overall safety culture) consists of six first-order observed variables (SC1, SC2, SC3, SC4, SC5, SC6). The observed variables are represented in rectangles and the latent variables are represented by circles. The hypothesis model proposed for this study tests the following five hypotheses and these are represented as shown in Figure 5.1.

- Hypothesis-1 (H1): Behavioural dimension (B) has a significant positive relationship with overall safety culture (SC).
- Hypothesis-2 (H2): Knowledge dimension (K) has a significant positive relationship with overall safety culture (SC).
- Hypothesis-3 (H3): Organization safety practices dimension (O_1) has a significant positive relationship with overall safety culture (SC).
- Hypothesis-4 (H4): Psychological dimension (P) has a significant positive relationship with overall safety culture (SC).
- Hypothesis-5 (H5): Organization policies, rules and regulations dimension (O_2) has a significant positive relationship with overall safety culture (SC).

This hypothesized relationship model (Figure 5.1) provides a theoretical foundation for modeling the factor structure of safety culture in construction industry. The hypothesized relationship model is analyzed through two kinds of evaluation. Firstly, the assessment of the measurement model for its reliability and validity was done; and secondly, the assessment of structural model by examining the exploratory power and path coefficients was carried out.

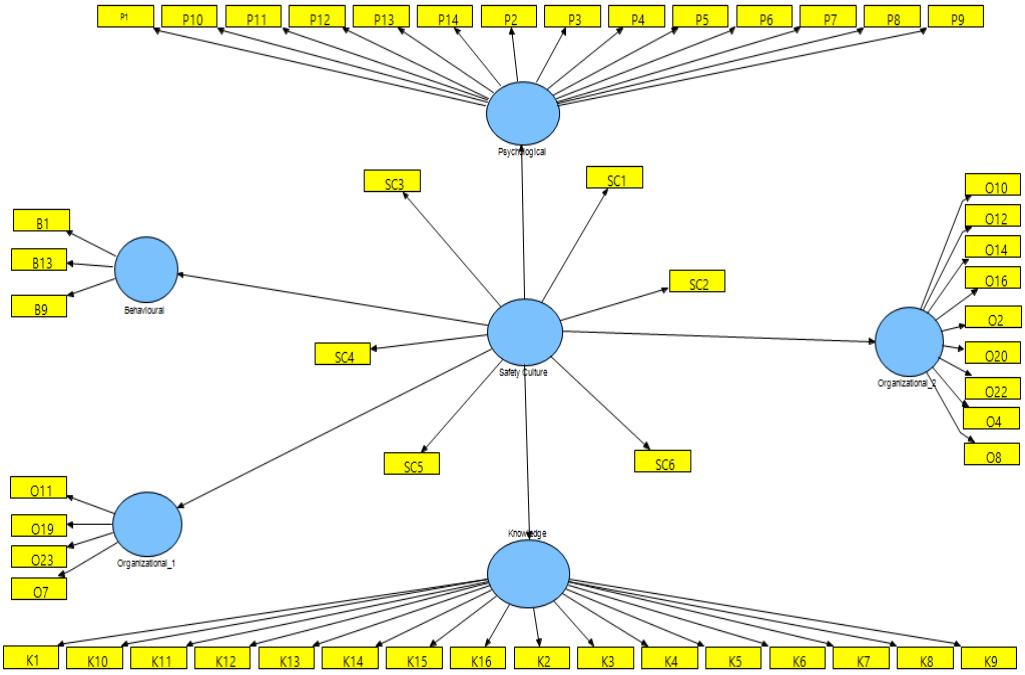


Figure 5.1 Hypothesized detailed relationship model

5.5.2 Assessment of measurement model

First step in using PLS-SEM technique is establishing the reliability and validity of the measurement model. During the assessment process of the measurement model, four types of reliability and validity measures need to be evaluated. They are: (i) internal consistency reliability; (ii) indicator reliability; (iii) convergent validity; and (iv) discriminating validity (Shan et al., 2015).

(i) Internal consistency reliability of the measurement model is evaluated by measuring the value of Composite Reliability (CR) which is recommended to be greater than 0.7 (Hair et al., 2012). From the analysis, all the CR values were over 0.7 (Table 5.5), indicating a satisfactory amount of reliability of internal consistency.

(ii) Indicator reliability is measured based on the loadings of the observable variables on the corresponding latent variables they intend to represent. The criteria considered in indicator reliability is, if the value of outer loadings is less than 0.4, then the factor is removed; and if the value of the loading is greater than 0.7, then the factor would be considered (Safitri et al., 2019). The recommended value of

the loadings is usually greater than 0.7 (Hair et al., 2012). Based on the analysis, all loading values were greater than 0.7, suggesting acceptable indicator reliability. Convergent validity is the extent to which a measure correlates with alternative measures of the same construct (Hair et al., 2016). The convergent validity of the measured constructs is evaluated using average variance extracted (AVE), composite reliability scores and Cronbach's alpha values (Trinh et al., 2018). The results of the convergent validity test are reported in Table 5.5. The results show that the AVE scores were higher than 0.5, the composite reliability scores and Cronbach's alpha values were greater than 0.7. AVE values greater than 0.50 denote a satisfactory convergent validity as it indicates that the construct explains 50% of the variance of its constituent factors (Hair et al., 2016). The value of CR should also be greater than 0.7 (Hussain et al., 2019). Thus, the measurable items were appropriate for their respective constructs.

(iii) Discriminant validity refers to the extent to which a given construct is different from another construct (Roldan and Sanchez-Franco, 2012). Results of discriminant validity test are reported in Table 5.6. The discriminant validity of the constructs is ascertained by comparing the square root of AVE scores and correlation coefficients between the latent constructs (Hair et al., 2016). From the table, each construct's square root of AVE values was greater than the correlation with other constructs. Accordingly, the results indicate that discriminant validity is satisfactory and correspondingly the five dimensions of safety culture are different from each other.

Table 5.5 Measurement model evaluation

Constructs	Item code	Outer Loadings	Average Variance Extracted	Composite reliability	Cronbach's alpha (α)
B: Behavioural dimension	B1	0.935	0.855	0.946	0.915
	B13	0.938			
	B9	0.900			
K: Knowledge dimension	K1	0.811	0.677	0.971	0.968
	K10	0.821			
	K11	0.822			
	K12	0.848			
	K13	0.805			
	K14	0.841			
	K15	0.831			
	K16	0.812			
	K2	0.854			
	K3	0.835			
	K4	0.822			
	K5	0.788			
	K6	0.823			
	K7	0.801			
	K8	0.843			
	K9	0.808			
O_1: Organization safety practices dimension	O11	0.900	0.816	0.947	0.925
	O19	0.919			
	O23	0.879			
	O7	0.915			
O_2: Organization policies, rules and regulations dimension	O10	0.872	0.745	0.963	0.957
	O12	0.871			
	O14	0.844			
	O16	0.852			
	O2	0.809			
	O20	0.895			
	O22	0.883			
	O4	0.877			
	O8	0.865			
P: Psychological dimension	P1	0.799	0.655	0.964	0.959
	P10	0.824			
	P11	0.805			
	P12	0.796			
	P13	0.841			
	P14	0.847			
	P2	0.830			
	P3	0.791			
	P4	0.778			
	P5	0.819			
	P6	0.827			
	P7	0.821			
	P8	0.806			
	P9	0.742			

Table 5.6 Correlation of latent variables and AVE values

	B	**K**	**O_1**	**O_2**	**P**
Behavioural (B)	*0.924*				
Knowledge (K)	0.728	*0.823*			
Organizational_1 (O_1)	0.699	0.754	*0.903*		
Organizational_2 (O_2)	0.753	0.809	0.778	*0.863*	
Psychological (P)	0.768	0.745	0.739	0.786	*0.809*
Note: Diagonal elements are the square root of AVE values					

The measurement model was therefore reliable and valid for structural path modeling, and the dimensions of safety culture were confirmed to be valid.

5.5.3 Assessment of structural model

The structural model defines the interaction among latent variables. It is the structural component of the model that allows an analyst to create substantial conclusions regarding the relationship of latent variables to the mechanism underlying a process or phenomenon (Molenaar et al., 2009). These latent variables can be quantified to better comprehend the complicated nature of the construction industry. The relationship between safety culture constructs (P, B, O_1, O_2, K) and overall safety culture (SC1, SC2, SC3, SC4, SC5, SC6) is tested using Structural Equation Modelling (SEM). The safety culture constructs are considered as latent variables in SEM model, whereas, the measurable items of each safety culture construct are derived from reliability and validity measures as explained in the previous section.

Once an agreeable assessment of measurement model is done, it is further possible to evaluate the structural model. The main focus of PLS-SEM is the prediction potential with an objective to maximize the variance of the dependent variables (Durdyev et al., 2018). The assessment criteria for evaluating the structural model are examining the exploratory power and path coefficients of the proposed model.

1. Examining the exploratory power of the proposed model: This is based on the coefficient of determination (R^2) value, which indicates the amount of variance and is a measure of the predictive power of the construct in question (Chin, 2010). From the analysis, R^2 values for Behavioural, Knowledge, Organizational_1,

Organizational_2, and Psychological dimensions are 0.608, 0.758, 0.551, 0.685, 0.558 respectively ($p < 0.05$), suggesting a satisfactory level of explanatory power of the structural model. Figure 5.2 shows the PLS-SEM model representing R^2 values and factor loading coefficients. The measure of R^2 value as suggested by Cohen (1988) determines the model validity and is regarded as weak (if the value of R^2 lies between 0.02 and 0.13), moderate (if the value of R^2 lies between 0.13 and 0.26) and substantial (if the value of R^2 is greater than 0.26). For example, R^2 value for knowledge dimension was 0.758, indicating that 75.8% of the variance in measure of overall safety culture is explained by the influence of knowledge dimension. Therefore, the proposed model confirms and validates the hypothesis statements of this study.

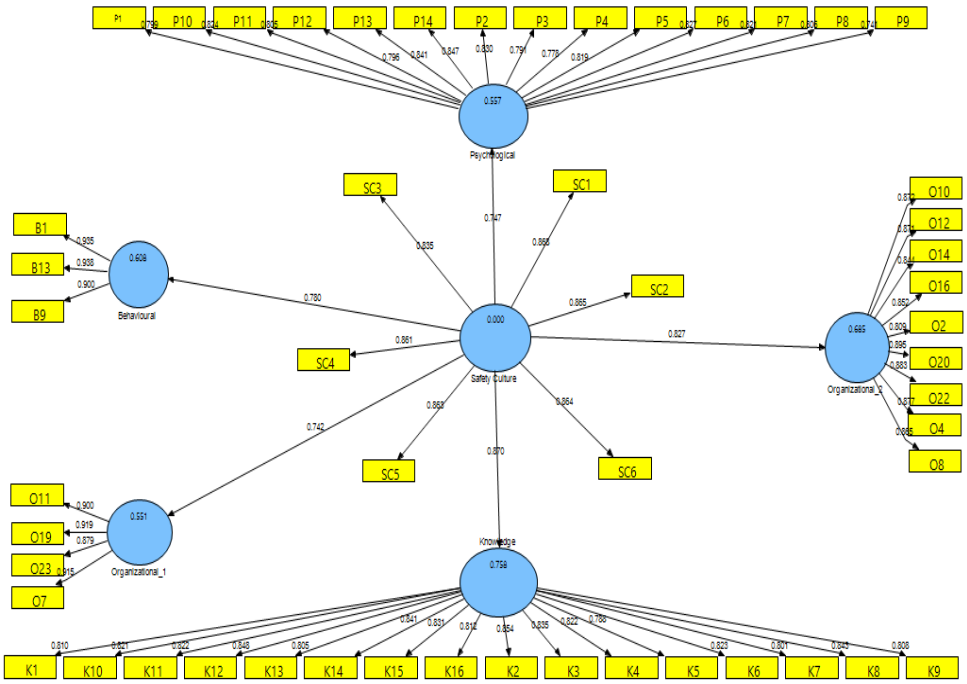


Figure 5.2 Initial path model

2. Path coefficients of the model: The path coefficient (β value) shows the strength and direction of the relationship between the variables (Huang et al., 2013). The proposed hypothesized relationship model is compared using the path coefficient (β) values of each path. A greater path coefficient (β) value indicates that it has a more substantial influence on the latent variable. The significance of path coefficient is computed through a t-test. In order to estimate the significance of the path coefficients, bootstrapping technique is employed using 2000 sub-samples

(Wetzels et al., 2009). Figure 5.3 presents the results of the structural model of knowledge-based safety culture constructs that show the t-statistics associated with each path. The relationships of influence between the variables were determined by t-statistics (Safitri et al., 2019). If the t-value is above 1.96, this indicates that the impact of one factor on another factor with the path coefficient being significant at $p \leq 0.05$. The value of 'p' indicates the level of significance and meaningful relationship (Safitri et al., 2019). Table 5.7 highlights the structural properties of the hypothesized knowledge-based safety culture model.

Table 5.7 Structural properties of the constructs

Relationship	Path coefficient	t-value	Is the relationship supported?
Safety Culture -> Behavioural	0.780	15.771*	Yes
Safety Culture -> Knowledge	0.870	22.987*	Yes
Safety Culture -> Organizational_1	0.742	13.139*	Yes
Safety Culture -> Organizational_2	0.827	20.475*	Yes
Safety Culture -> Psychological	0.747	10.867*	Yes
Note: * $p<0.05$			

Results indicate that all safety culture constructs have a positive influence on overall safety culture. The t-statistics score of all constructs was greater than 1.96, indicating the effect is significant. Table 5.7 demonstrates that safety culture and knowledge dimension have a standardized path coefficient of 0.870 and t-value of 22.987. This indicates that dearth of knowledge related to safety issues has a major influence on safety culture, and thereby it indicates that it has the most significant effect on overall safety culture in construction projects. Hence, the results support the proposed research hypothesis of the study. Therefore, the hypothesis that knowledge dimension significantly influences safety culture in construction industry is accepted and proven.

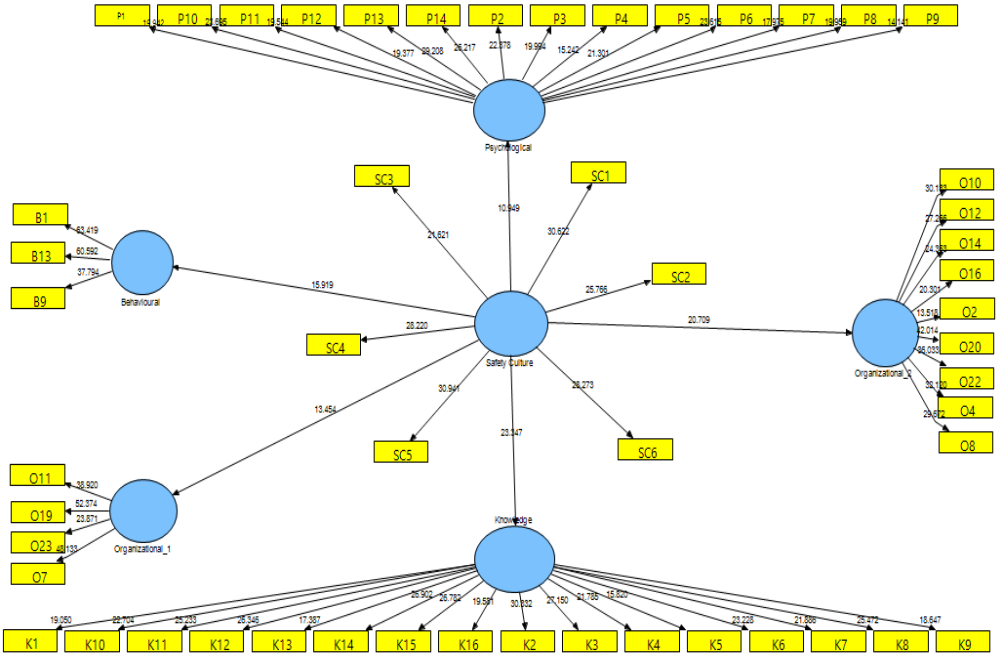


Figure 5.3 Final path model

Assessment of overall fit of the model is calculated by Global fit measure i.e. Goodness-of-Fit (GoF) value. This is an index used to validate the partial least squares path model globally (Tenenhaus et al., 2005). GoF value is calculated as the geometric mean of average communality value and average R^2 value of the latent variables. GoF value of 0.688 for the complete model is obtained, which is greater than the cut-off value for GoF large (0.36) effect sizes (Henseler and Sarstedt, 2013). This indicates that the empirical data used for the study fit very well with the model and has the greater power to explain the model.

PLS-SEM method was established for prediction determinations of the hypothesized safety culture constructs. From the results of PLS-SEM, it can be inferred that all safety culture constructs including the neglected knowledge dimension are effective in explaining the overall safety culture of construction industry.

5.6 DISCUSSION

5.6.1 Development of knowledge-based safety culture measurement scale

The measurement scale developed to measure knowledge-based safety culture in construction organizations consisted of 69 factors grouped into four dimensions of safety culture. From the results of the analysis, the designed instrument is expected to concisely measure safety culture in Indian construction organizations. In addition, the study has presented a comprehensive methodology that can be adopted in other industries, different cultural contexts, and regions that share similar such environment to effectively measure the influence of knowledge management strategies required to improve safety culture in their organizations.

Based on the result of the analysis, the study has explained the significant importance of knowledge dimension on the level of safety culture. Knowledge dimension received the highest mean value of 3.77 with a least standard deviation of 0.78 among other dimensions; indicating better consciousness among individuals about the importance of knowledge management strategies required to improve safety culture in their organizations. Also, knowledge dimension has obtained the highest path coefficient of 0.870 and a percentage of variance of 4.117% among other safety culture constructs.

Out of 69 factors of the finalized measurement scale, 46 factors were found to represent knowledge-based safety culture in construction organizations which was able to explain a total variance of 70.805%. All the factors in consideration to knowledge dimension have a factor loading greater than 0.70. This indicates that knowledge dimension consisting of both tacit and explicit knowledge is essential for improving safety culture in construction industry (Sherehiy and Karwowski, 2006; Fargnoli et al., 2011). Safety as a form of organizational expertise is therefore situated in the system of ongoing practices that has both explicit and tacit dimensions. Moreover, the present study highlights the relationship that includes management of tacit and explicit knowledge aspects on employee's perception of safety on attitude, behaviour, and practices and thereby facilitating and enabling safety culture to be embedded in organization practices. Moreover, to effectively utilize the knowledge, it is necessary to create a suitable climate and conditions in an organization that would trigger employee's

involvement and commitment in knowledge-based activities (Podgórski, 2010). More importantly, effective dissemination of this knowledge shapes safety culture within the organization (Järvis et al., 2014). Analysis results show that organizations should give utmost consideration to explicitly manage knowledge in order to develop a positive safety culture in the organization. Most importantly, suggested constructs of knowledge management can also be broken down into measurable factors that provide a thorough state of mind about numerous procedures and perspectives that may affect safety culture with respect to managing knowledge in construction industry. For example; (i) adopting proper safety guidelines or policy grants knowledge sharing mechanism throughout the organization by dedicated safety training sessions, demonstrations, meetings etc.; (ii) safety programs synthesize different perspectives on hazards in the workplace by integrating different knowledge assets (records and databases) related to occupational safety; (iii) actions that are needed to assure a proper and safe execution of working activities aim to acquire worker's knowledge and skills to learn the best practices and the lessons learned are captured in organization's records and databases that can be reused in future; (iv) organization knowledge needs to capture the best practices and lessons learned with the aim of developing knowledge storage units for the employees. However, mere implementation of safety policies and guidelines may not bring effectiveness due to the difficult nature of knowledge management practices (Aboagye-Nimo et al., 2015). Hence, it is important to integrate appropriate controlling and monitoring in the implementation process for continuous improvement of knowledge management practices within the organization.

Discriminant validity results of the analysis suggest that there was a significant difference detected among a few parameters on the factor structures of the constructs. If there exists any significance among these factors, then the whole dimension is considered significant to that particular demographic profile (Agumba and Haupt, 2014). Some of the key findings are: previous safety culture studies primarily focused on large companies and neglect the significance of safety culture in small and medium-scale construction companies and lack establishing relationships across these groups. This study overcomes this issue by considering different size of projects based on number of employees in the organization, and the general perception of knowledge-

based safety culture importance on OSHAS certified and non-certified companies suggest that there is a significant difference among these sets of groups.

Besides determining the specific knowledge-based safety culture dimensions for construction organizations operational in Indian construction industry, the study has also attempted to validate the safety culture measurement scale. However, there exists a discrepancy in the factor structure resulting in five dimensions and resulting in elimination of some of the factors as identified from literature. This is due to the variations in the expectations of the respondents, safety knowledge of respondents, changes in rules and regulations of the organization, inexperience of the respondents, impact of safety certification on the organization (Cigularov et al., 2013; Zahoor et al., 2017).

Furthermore, the focus on the highlighted knowledge-based safety culture factors is believed to help in improving safety culture and thus enhancing safety performance in construction organizations. This will, in turn, contribute towards profitability and sustainability as a result of decrease in variable expenses like accident costs, compensation costs, rate of accidents, and incidents, etc. (Gaureanu et al., 2016). The developed knowledge-based safety culture measurement model can be used to benchmark the safety culture practices of construction organizations.

5.6.2 Causal relationship between knowledge-based safety culture constructs and overall safety culture

Results of exploratory factor analysis provide a better explanation of the component structure. While some of the important aspects were not perceived through this analysis, such as the existence of correlation among the constructs and its influence on the overall safety culture, a systematic approach was adopted to test and validate the influence of knowledge-based safety culture constructs on overall safety culture among Indian construction organizations. The casual association between 46 factors of safety culture that were grouped under five dimensions of knowledge-based safety culture was examined by conducting a confirmatory factor analysis. PLS-SEM approach was used to evaluate the interdependency between knowledge-based safety culture constructs and overall safety culture with its associated factors. The number of observations for

the model was 210. The proposed PLS-SEM generally fits well. The developed model achieved an acceptable degree of internal consistency reliability, indicator reliability, convergent reliability, discriminating validity, and composite reliability. Further, the model also achieved the desired coefficient of determination value, path coefficient, and goodness-of-fit measures.

Results of the proposed structural model indicated that knowledge-based safety culture constructs with underlying factors contributed to overall safety culture. All five constructs positively contributed to improving overall safety culture of construction organization, in terms of; managing safety culture as a change process (SC1), making sure the business follows relevant safety culture initiatives (SC2), review of the current practices of safety management at the organization level (SC3), defining safety leadership roles and accountabilities (SC4), commitment towards occupational health and safety rules and regulations (SC5), and importance of safety certification for improving safety culture in your organization (SC6).

Among the five constructs, the path coefficients between knowledge dimension and contribution to overall safety culture were achieved to be greatest (0.870) among other constructs. It is consistent with the expectation that effective knowledge management strategies could promote knowledge sharing among individuals (Järvis et al., 2014) and enhance cultural aspects related to safety in construction organizations (Chuks and Uchenna,2013).

Based on the analysis, the relevant factors contributing to the improvement of safety culture in organizations are explained in detail.

- Knowledge management factors have obtained highest importance among other constructs. Among them, first is the importance of safety regulations to prevent accidents and incidents at the workplace (K2), which has achieved the highest loading on knowledge dimension (0.854). The importance of knowledge related to safety regulations mainly provides awareness of relevant provisions, duties and adequate requirements of documentation like safety plan, safety risk assessment, etc. Next, is the perpetual and cognitive skill required to work safely (K12), which is essential as it focuses on individual views about the safety situation at the

workplace (Williamson et al., 1997). There is a need for the presence of integrated safety documentation system (K8) at organizations; this ensures the availability of safety procedures in the organization at the right time (Glendon and Litherland, 2001). Next important factor is clear understanding of thumb rules of safety (K14). Although this knowledge is hard to verbalize, it ensures efficient occupational safety and health management in organization that is required to explore tacit knowledge that is hidden in minds of experienced individuals at all levels of organization (Podgórski, 2010).

- Among organization safety policies, rules and regulations factors, storing safety-related matters in organization memory and building safety knowledge management system as well as implementation of safety plans are important factors under consideration. This is due to the reason that knowledge sharing helps to retrieve knowledge from the organization's memory and makes it accessible to employees whenever it is required (Leidner et al., 2006). Also, the importance of safety planning serves as a fundamental step for managing construction health and safety and thus establishes a good safety culture (Zhang et al., 2015).
- In behavioural dimension, modelling safe work practices are essential in order to effectively implement safety rules combined with safe working methods as it helps to prevent potential hazards at workplace (Hon et al., 2013) and hence safety processes need to be aligned with safe work practices that would influence the behaviour of individuals (Zahoor et al., 2017).
- The importance of organizational safety practices is attributed to management of safety-knowledge and being in accordance with safety compliance put up by the organization in view of safe practices. Managing safety knowledge contributes to enacting, understanding, designing, implementing, monitoring and controlling safety programs in the organization (Masood et al., 2012). Being in accordance with safety compliance of the organization such as safety regulations, rules, practices, codes and conducts helps to reduce accident frequency (Subramaniama et al., 2017).
- Psychological factors that contribute to improving safety culture at organizations are presence of occupational health and safety expertise and safety mentoring process. Occupational health and safety experts are important as they share concern towards a problem and provide a set of solutions to the problem by regular

interaction among the employees that are related to safety aspects (Podgórski, 2010). Safety mentoring process emphasizes to peer on safety care under pressure and care about peer's safety awareness and mentor to peer about working safely in an organization (Brondino et al., 2013).

All of these knowledge-based safety constructs support the improvement of overall safety culture. The factors that signify the measure of overall safety culture are;

- Managing safety culture as a change process (SC1) foster a shared innovative spirit and obtain a proactive attitude in the organization. During this cultural change process, crucial decisions are made to avoid uncertainty in safe work actions. Management is emphasized to regularly look for feedback about the change process from all employees (Grote, 2008).
- Making sure the business follows relevant safety culture initiatives (SC2) – the experiential knowledge of the employees has the potential to inhibit the dissemination of good safety practices. Initiatives that do not make use of this knowledge may fail to fully address hazards and new methods of learning (Rooke and Clark, 2005).
- Defining safety leadership roles and accountabilities (SC4) promotes the development of positive safety culture which has the ability to improve safety in construction organizations. In order to eliminate the negative impact resulting in accidents or incidents, commitment and support of the management are essential which is directed by defined roles and responsibilities of the project managers to perform safety tasks (Sunindijo and Zou, 2012).
- Commitment towards occupational health and safety rules and regulations (SC5): consists of strategic and tactical rules of safety management that are formulated at the organization level which comes from top management's policy actions and that will be applied and experienced through front-line workers practical actions (Gao et al., 2016).
- Importance of safety certification for improving safety culture in organizations (SC6) seeks to improve safety practices that contribute to enhance safety performance (Abad et al., 2013; Vinodkumar and Bhasi, 2011).

On the basis of these implications, it is strongly believed that reliable safety culture measurement scale could provide proactive information on safety issues before accidents or incidents occur (Seo et al., 2004). Although the findings will not match actual levels of safety performance, construction organizations should focus on improving safety at the organizational level. This shifts its focus on changing unsafe acts and situations occurring at the workplace that are result of individual's attitude, behaviour, perception, and beliefs about safety. Many studies across various domains have implied the importance of employee's perception that highlight efficacy of safety system in an organization, but within an organization, there is always a need for physical change (Cooper and Phillips, 2004). This can be achieved by designing an interactive learning environment and effective learning possibilities to support knowledge management activities that are related to safety in the organization.

5.7 CHAPTER SUMMARY

This chapter outlines the results of data analysis and discusses the key findings pertaining to second objective of the study i.e., to assess the relevance of identified factors and evaluate the degree of their interdependency. The main objective of this study was to develop a safety culture measurement scale that consisted of underlying factors and based on the sampling frame designed for the study, the questionnaire survey data were collected comprising of 210 responses from several construction organizations in India. On suitably assessing the measurement scale, 46 factors that represent five knowledge-based safety culture constructs (i.e. behavioural dimension, knowledge dimension, organization safety practices dimension, psychological dimension and organization policies, rules and regulations dimension) were obtained as a result of exploratory factor analysis and this was further validated for assessing the degree of interdependency existing among five constructs with 46 underlying factors that influence overall safety culture in construction organizations. This study employed PLS-SEM method to test the hypothesized relationship model proposed for examining the influence of safety culture constructs, i.e., whether a significant relationship exists between these constructs and on overall safety culture. The model obtained as a result of PLS-SEM to determine the causal relationship of knowledge-based safety culture factors pertaining to construction industry offers a robust tool to analyze an

organization's safety culture. The results showed that the influence of knowledge-based safety culture has positive and significant impact on overall safety culture in the construction industry. Therefore, the final survey instrument was proved to be an effective measurement tool to measure the knowledge-based safety cultural aspects of construction organizations.

CHAPTER 6

DEVELOPMENT OF ASSESSMENT FRAMEWORK FOR KNOWLEDGE-BASED SAFETY CULTURE IN CONSTRUCTION INDUSTRY

6.1 INTRODUCTION

The importance of knowledge-based safety culture factors has been ascertained in detail in the previous chapters based on their relevance and degree of interdependency existing between these factors. In this section, a detailed methodology to develop an assessment framework for evaluating overall safety culture in construction industry has been formulated. Firstly, a measurable quantitative framework has been formulated based on the importance of factors in shaping a positive safety culture in construction industry. Later, the importance of these factors is verified by comparing the assessment scores in different case scenarios of construction industry.

6.2 QUANTITATIVE FRAMEWORK

Improvements that could inevitably contribute to continuous monitoring and reviewing safety culture is necessary in any construction organization. In order to achieve this, a quantitative assessment framework for safety culture is required. This comprehensive framework takes into account the most pertinent factors relevant to construction industry. Factors considered in formulating the assessment framework are based on their importance towards improving safety culture in any construction organization. This framework is developed based on the results of the questionnaire survey. Next section highlights the protocol for formulating the assessment framework.

6.2.1 Development of quantitative framework

Many countries have embraced a self-regulatory strategy to assess safety management system in terms of its development, implementation, and maintenance. Most importantly, a good safety management system is vital to impulse an adequate safety culture in organizations (Remawi et al., 2011; Bahn, 2013). In this regard, safety objectives and targets are set to measure the effectiveness of the assessment approach. In addition to setting these goals, construction organizations need a rational framework for assessing safety culture in their organizations.

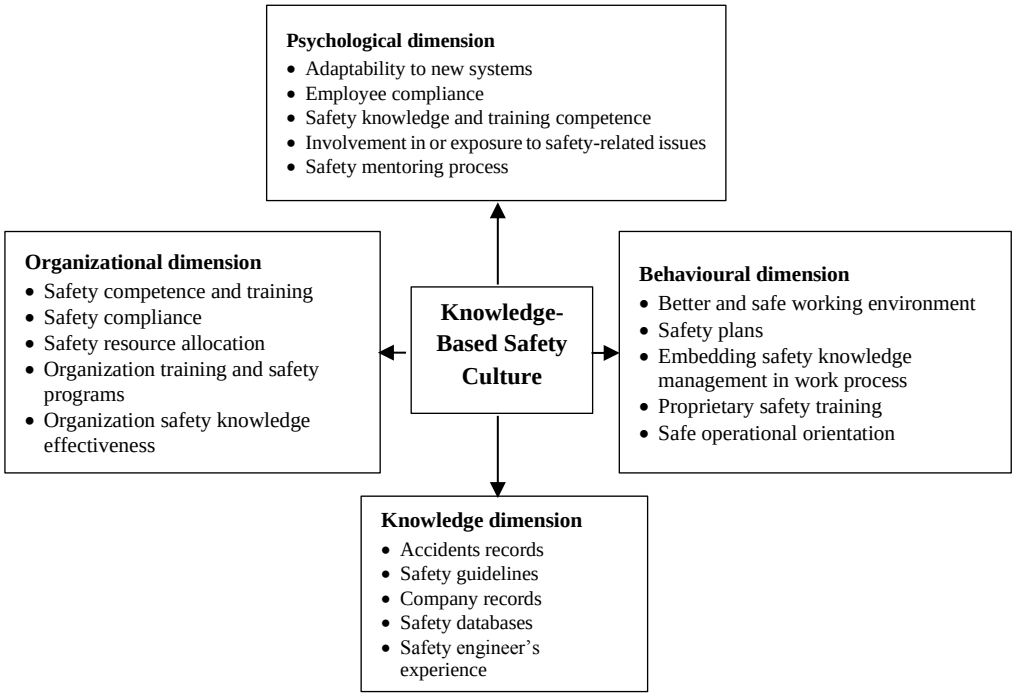


Figure 6.1 Construction knowledge-based safety culture framework

The most pertinent factors affecting safety culture in construction organizations are studied through a questionnaire survey conducted in Indian construction industry. Based on the importance of the identified factors, an assessment framework is formulated. Questionnaire survey is utilized in formulating the main factors and sub-factors among the identified factors. Main factors include psychological dimension, behavioural dimension, organizational dimension, and knowledge dimension. An effective safety culture framework is developed on the basis of the importance of main and sub-factors affecting overall safety culture in construction industry and is illustrated

in Figure 6.1. Further, this model has been used to generalize the empirical results of the case scenarios (Section 6.4).

6.2.2 Importance of main factors

Data collected from survey were analyzed using the technique adopted by Ng et al., (2005) to obtain Mean Score for each main factor and is computed as:

$$\text{Mean Score (MS)} = \frac{\sum f * r}{N} \; (1 \leq \text{Mean Score (MS)} \leq 5)$$

where, 'f' is frequency of respondents rating each of the main factors; 'r' is rating given by each respondent to main factor; 'N' is the total number of respondents.

Further, based on the mean scores computed for each of the main factors, Relative Importance was calculated using the formula:

$$\text{Relative Importance } (RI_i) = \frac{MS_i}{\sum_{i=1}^{N} MS_i}$$

where, 'RI_i' is relative importance of i^{th} main factor and 'MS_i' is Mean Score of i^{th} main factor.

Based on the above calculation, summary of mean scores and relative importance of main factors are computed and shown in Table 6.1. Results revealed that all main factors (i.e. four safety culture dimensions) are critical for construction safety because the mean score of these factors is greater than the median value (i.e., greater than 3). Among them, Knowledge dimension is the most important factor and Psychological dimension is the least important factor. This is in line with the research findings as explained in the earlier section (refer section 5.3).

Table 6.1 Summary of mean score of main factors of safety culture

Dimensions	**Mean Score (MS)**	**Relative Ranking**	**Relative Importance (RI)**
Knowledge dimension	3.77	1	0.256
Organizational dimension	3.67	2	0.250
Behavioural dimension	3.64	3	0.248
Psychological dimension	3.62	4	0.246

6.2.3 Importance of sub-factors

In order to establish the importance of each sub-factor underlying each of the main factors, similar computation has been adopted.

$$\text{Mean Score } (MS_{sub}) = \frac{\sum f * r}{N} \; (1 \leq \text{Mean Score } (MS_{sub}) \leq 5)$$

where, 'f' is frequency of respondents rating each sub-factor; 'r' is rating given by each respondent to sub-factor; 'N' is the total number of respondents.

Further, based on the mean scores computed for each sub-factor, Relative Importance was calculated using the formula:

$$\text{Relative Importance } (RI_{ij}) = \frac{MS_{ij}}{\sum_{i=1}^{N} MS_{ij}}$$

where, 'RI_{ij}' is relative importance of j^{th} sub-factor under i^{th} main factor and 'MS_{ij}' is Mean Score of j^{th} sub-factor under i^{th} main factor.

Based on the above calculation, summary of mean scores and relative importance of sub-factors under each of main factors are computed and shown in Table 6.2. Results revealed that "following safety guidelines (rules and regulations) that comply with safety standards" is most important sub-factor under knowledge dimension; while "involvement in or exposure to safety-related issues fosters physical experience" is least important sub-factor under psychological dimension. Also, from the table, it is evident that most critical sub-factors fall under 'knowledge' as the main factor. Sub-factors such as "maintaining accidents records for analyzing the type and severity of accident occurring at the workplace", "safety engineer's experience contributes to work safely", and "essential requirement of company records that conform with safety policies of the organization" can also be stated as critical sub-factors contributing to overall safety culture. This also signifies that all measurable factors under knowledge dimension are critical to evaluate overall safety culture in construction industry.

Table 6.2 Summary of mean score of sub-factors of safety culture

Main factor and sub-factors	**Mean Score (MS)**	**Relative Ranking**	**Relative Importance (RI)**
Knowledge dimension (RI = 0.256)			
Maintaining accidents records for analyzing the type and severity of accident occurring at the workplace	3.871	2	0.202
Following safety guidelines (rules and regulations) that comply with safety standards	3.876	1	0.197
Essential requirement of company records that conform with safety policies of the organization	3.833	4	0.200
Availability of safety databases in the organization	3.829	5	0.200
Safety engineer's experience contributes to work safely	3.862	3	0.201
Organizational dimension (RI = 0.250)			
Safety competence and proper training of managers	3.724	7	0.201
Being in accordance with safety compliance	3.690	13	0.199
Allocation of safety resources whenever necessary	3.690	14	0.199
Organization training and safety programs to develop safety knowledge	3.709	10	0.200
Organization safety-knowledge effectiveness	3.729	6	0.201
Behavioural dimension (RI = 0.248)			
Better and safe working environment for employees	3.667	19	0.199
Existence of safety plans for emergencies	3.719	8	0.201
Embedding safety knowledge management in the work process	3.671	17	0.199
Proprietary safety training (videos and demonstrations)	3.719	9	0.201

Orientation and training are essential to perform operations safely	3.686	15	0.200
Psychological dimension (RI = 0.246)			
Adaptability to new systems	3.705	11	0.201
Employee compliance towards safety standards	3.696	12	0.201
Safety knowledge and training competence of employees	3.671	18	0.200
Involvement in or exposure to safety-related issues fosters physical experience	3.652	20	0.198
Safety mentoring process	3.676	16	0.200

Accordingly, the study findings indicated that all main and sub-factors are essential to contribute to overall safety culture because the mean score values are greater than the average value. For further assessment, the next section discusses in detail the formulation of Safety Culture Index.

6.3 SAFETY CULTURE ASSESSMENT FRAMEWORK

Safety Culture Index (SCI) is calculated for each sub-factor in the development of safety culture assessment framework. This is done by combining the Relative Importance (RI) values of each sub-factor and its corresponding main factor (i.e. safety culture dimensions). The combined score is determined to be a weighted score to form the Safety Culture Index (SCI). The score obtained to formulate the index is assumed to represent the actual safety culture practices of any construction organization.

$$\text{Safety Culture Index}\left(\text{SCI}_{ij}\right) = \frac{\text{WS} * \text{RI}_{ij} * \text{RI}_{i}}{4} * 100$$

where, SCIij is the safety culture index of j^{th} sub-factor under i^{th} main factor; WS is weighted score of different safety culture factors based on the level of importance; with '1' being 'poor', '2' being 'satisfactory', '3' being 'good', and '4' being 'very good'.

For instance, safety culture index for measure considered as 'very good' (WS = 4) safety culture practices in "maintaining accidents records for analyzing the type and severity of accident occurring at the workplace" is computed as:

$$\left(\mathrm{SCI}_{\text{maintaining accident records}}\right) = \frac{4 * 0.202 * 0.256}{4} * 100 = 5.17$$

After computing all potential index values for all sub-factors under each main factor that is based on the above-defined scenarios (i.e. from "poor" to "very good"), an assessment form can be articulated to assess safety culture of any organization. The detailed safety culture assessment framework developed is shown in Annexure-D. With the evaluation form, project managers can compute safety culture scores by summing up the scores of all sub-factors under each main factor.

6.4 EVALUATION OF ASSESSMENT FRAMEWORK IN CONSTRUCTION ORGANIZATIONS

Aim of developing quantitative assessment framework consisting of main and sub-factors is to depict overall safety culture is any construction organization. To uncover the importance of each sub-factor underlying each main factor developed from the assessment framework contributing to shaping a positive safety culture in any construction organization, different case scenarios have been undertaken. This comprises of multiple cases drawn from different sources of evidence that aim to offer meaning in the context and demonstrate a thorough knowledge of the key problems and helps to focus on a specific organization based on a particular situation or a context (Oyewobi, 2014); which in this case is the study on improving safety culture in construction organizations. In this regard, a comparison is made to assess the perception of OHSAS 18001:2007 certified and non-certified construction organizations. Case scenarios of different organizations were considered for comparing the safety culture scores resulting from the developed assessment framework. A sample of determining the safety culture score with the assessment framework developed is shown in Table 6.3.

Table 6.3 Knowledge-based safety culture assessment framework

Factors affecting knowledge-based safety culture	Level of importance				Score	Total
	Poor (value * 1)	Satisfactory (value * 2)	Good (value * 3)	Very Good (value * 4)		
Knowledge dimension						
Maintaining accidents records for analyzing the type and severity of accident occurring at the workplace	1.29	2.59	3.88	5.17	20.68	Sub-total 1
Following safety guidelines (rules and regulations) that comply with safety standards	1.26	2.52	3.78	5.04	20.16	
Essential requirement of company records that conform with safety policies of the organization	1.28	2.56	3.84	5.12	20.48	
Availability of safety databases in the organization	1.28	2.56	3.84	5.12	20.48	
Safety engineer's experience contributes to work safely	1.29	2.57	3.86	5.15	11.58	93.38
Organizational dimension						
Safety competence and proper training of managers	1.26	2.51	3.77	5.02	20.08	Sub-total 2
Being in accordance with safety compliance	1.24	2.49	3.73	4.98	11.19	
Allocation of safety resources whenever necessary	1.24	2.49	3.73	4.98	19.92	
Organization training and safety programs to develop safety knowledge	1.25	2.50	3.75	5.00	20.00	
Organization Safety-knowledge effectiveness	1.26	2.51	3.77	5.03	11.31	82.50
Behavioural dimension						

Better and safe working environment for employees	1.23	2.46	3.69	4.93	11.07	
Existence of safety plans for emergencies	1.25	2.50	3.75	5.00	20.00	
Embedding safety knowledge management in the work process	1.23	2.47	3.70	4.93	19.72	Sub-total 3
Proprietary safety training (videos and demonstrations)	1.25	2.50	3.75	5.00	20.00	
Orientation and training are essential to perform operations safely	1.24	2.48	3.71	4.95	19.80	90.59
Psychological dimension						
Adaptability to new systems	1.24	2.48	3.72	4.95	11.16	
Employee compliance towards safety standards	1.24	2.47	3.71	4.94	11.13	
Safety knowledge and training competence of employees	1.23	2.45	3.68	4.91	11.04	
Involvement in or exposure to safety-related issues fosters physical experience	1.22	2.44	3.66	4.88	10.98	Sub-total 4
Safety mentoring process	1.23	2.46	3.69	4.91	19.64	63.95

Safety culture score = Subtotal 1 + Subtotal 2 + Subtotal 3 + Subtotal 4 = 330.42 (good)

Based on the above safety culture score, benchmarks are established as follows:

1. if the total safety culture score is between 25 and 100, the safety culture in the organization is poor;
2. if the total safety culture score is between 100 and 225, the safety culture in the organization is satisfactory; and
3. if the total safety culture score is between 225 and 400, the safety culture in the organization is good.

Case scenarios for assessing safety culture scores were considered among four organizations. Among them, Case-1/Organization 1 and Case-3/Organization 3 were OHSAS 18001:2007 certified and Case-2/Organization 2 and Case-4/Organization 4 were non-certified organizations. Scores obtained from these organizations revealed that all organizations have good safety culture practices in their organizations (Figure 6.2). Additionally, certified organizations performed better in comparison to non-certified organizations.

Figure 6.2 Case comparisons of safety culture score in organizations

Further, results of the score based on the measurable factors were ensured by respective professionals in these organizations and were ascertained whether the formulated framework truly reflects knowledge-based safety culture practices in their organization. In this regard, interviews were conducted to understand cultural aspects related to safety in order to define possible approaches for improvement of safety culture in construction organizations which consisted of both OHSAS 18001:2007 certified and non-certified organizations. Interviews were conducted among professionals of these organizations with a focus on key factors that contribute to development of overall safety culture and exploring the complex issues that need improvement in association with safety culture practices in construction organizations. Data collection from these organizations was related to the formulated conceptual model (Section 6.2.1) that links the key factors and

shows their impact on overall safety culture. Detailed semi-structured questions formulated have been shown in next section.

6.5 INTERVIEW ANALYSIS

Aim of this study was to further examine in greater detail the perceived knowledge-based safety culture factors that affect overall safety culture which in turn influence safety performance in construction organizations. In this regard, investigation was done to understand how well the interviewees are acquainted with deemed significant knowledge management strategies that influence safety culture. It was believed that their perceptions of important practices would indicate the prevailing culture and reveal key factors that shape a better and positive safety culture in construction organizations. Questions that were asked to the interviewees focusing on prevailing safety culture of the organization are:

a) Is the present organization OHSAS 18001:2007 certified? If yes, what is the impact of certification credentials on improving safety standards of the organization? If no, what is the mechanism present in the organization to adhere to the safety standards?
b) What is your general opinion on safety culture and what are the important aspects that can cultivate a good safety culture in an organization?
c) How do you perceive the importance of knowledge management strategies required to improve the safety culture aspects in construction organizations?
d) What are the barriers to adapt or implement knowledge management strategies for developing safety culture in construction organizations?

The aim of the interviews was to understand the conceptions of safety culture that is influenced by knowledge management strategies by interviewing key personnels in OHSAS 18001:2007 certified and non-certified construction organizations. It also aimed to define divergences in organizational features, competitive policies, resources and capacity; and to study how those contributary factors interact with the company setting that affects the efficiency of organizations. Further, the impact of certification credentials was studied based on the understanding levels of these professionals. Focus of these questions was approached from a more practical perspective on the most

pertinent factors as identified from assessment framework (section 6.2.1). In addition to this, in-sights of existing safety management practices were elicited by both certified and non-certified organizations. After obtaining an overall picture of knowledge management strategies that influence the prevailing safety culture, detailed questions were asked to obtain a clear conception of each of the factors of safety culture dimensions. The interviews revealed some of the best practices and highlighted the strengths when describing their strategies; these are considered as supporting factors for improving safety culture. Lastly, an emphasis is made on conditions that hinder the adaptation or implementation of knowledge management strategies for developing safety culture in construction organizations.

6.5.1 Methodological issues

Advocates for an interview claim that group dynamics can impair the expression of opinions of people who are unsettled or unable to express their views in social circumstances (Jones, 2014). Nevertheless, it has been determined that one-to-one interviews represent the strongest analytical approach to investigate the topics because of its sensitivity and an underlying blame culture. This approach has the potential to explore the underlying themes highlighted in developing the framework, as opposed to group interviews. In this regard, in-depth interviews were conducted with senior representatives of the respective organizations (case scenarios) who had rich experience in organization's safety practices.

6.5.2 Sampling frame

Interview respondents are identified using a critical case sampling approach. Critical case sampling ensures cases that are considered are likely to provide most information related to the topic of discussion (Patton, 1990; Hansen, 2006). The advantage of this sampling technique is the choice of cases with rich data (i.e., in this case, OHSAS 18001:2007 certified or non-certified organizations). Informative cases were chosen so that investigators could learn a lot about problems that are related to the factors that affect safety management practices in the organization. It was therefore considered significant to select employees in the organization who have had an impact on or engaged in safety or organizational activities within the organization. Therefore,

individuals with rich experience and knowledge of the activities, procedures, and safety related issues were interviewed. These respondents are most likely to have awareness and are in significant management and leadership positions in their respective organizations. These include project managers, project engineers and other professionals from senior management levels. The background of the interviewees including their position, experience etc. are indicated in Table 6.4. These participants had also completed the main survey questionnaire. Interviews were conducted in a private setting using the interview guide as discussed earlier in section 6.5. Interviews were tape-recorded and transcribed verbatim.

Table 6.4 Background of the interviewees

Case	Interviewee	Experience (in years)	Position of the interviewee
1	A	28	Senior Deputy General Manager
	B	06	Assistant Manager
	C	08	Assistant Construction Manager
2	D	12	Project Manager
	E	08	Safety Manager
3	F	17	Assistant General Manager
	G	10	Project Manager
4	H	06	Managing Director
	I	06	Project Engineer

6.5.3 Data analysis

Interviews were conducted among four different organizations and these interview sessions were nearly an hour. All interviews were transcribed verbatim. This resulted in large volume of textual content. It was important to examine and interpret all this data. In the interpretive process, it was necessary to develop an analytical approach so that the findings were descriptive and robust. Critical interview responses that were deemed suitable in explaining the context were considered and explained in detail for interview analysis.

6.5.3.1 Impact of certification credentials on safety culture

It appears from literature review that studies investigating the relationship between implementation of safety certification and its impact on safety standards of the organization are unexplored and are not primarily studied in Indian context. This indicates a gap in the literature that needs to be explored in relation to safety management. Despite industrial accidents increasing and health, product and environmental losses increasing, more and more companies are voluntarily applying for safety certification. Hence, there is a need for investigating the relationship between safety management practices which is being affected by embracing safety certification that influences overall safety culture. The impact of certification as perceived by certified organizations are summarized below:

Case 1: *"Yes, the present organization is OHSAS 18001:2007 certified company. The safety practices are in line with the OHSAS standards. This allows organization to develop and implement a safety policy, establishes objectives and processes for achieving the commitments of policy and helps to take the necessary actions to improve performance [firm's]."*

Case 3: *"Yes, this [firm] is a certified organization. Adopting this standard enhances working conditions and reduces risks about possible accidents [injuries and fatalities rates]. It thereby protects both human capital and corporate reputation. This [certification credentials] improves firm's relations with its stakeholders."*

On the other hand, the impact of certification as perceived by non-certified organizations is summarized below:

Case 2: *"No. We have a variety of safety control to minimize safety risks of employees. We have a system to record and monitor accidents and fatalities. Workers are adequately trained at job sites more frequently in ways such as; tool-box meetings, pep-talks, at least twice in a work week. We have a separate vertical for safety implementation where we follow all safety regulations as per OHSAS. Labour force is the core strength of any construction company and we strongly believe in it. Safety is kept as first priority even before quality and money. With less illness and injury, we*

also gain more productive working hours, which leads to better profitability. In the long term, we also build a good reputation for our business and it is helping to retain staff. Also, a separate wing or vertical is established where we have trained safety engineers for every project who works under regulations of OHSAS. We have standard operating procedures defined and it will be followed for all the activities."

Case 4: *"No. Our company [firm] focuses on the product delivered based on the requirements of the customer [end-user]. So, safety is a key concern in achieving this objective. We [firm] adopt safety management methods that include recognition and incentives to motivate workers to work safely."*

A comparison of safety culture scores among these organizations revealed that certified organizations have a better score indicating better safety management practices in these organizations. Also, it is suggested to go for certification not only to equip themselves for competing in the international market but also to strengthen safety standards in order to reduce accidents, loss of production and workers' compensations (Vinodkumar and Bhasi, 2011). Assessment of safety performance in construction organizations contribute to measuring safety performance and could be evaluated by physical safety conditions as well as maintaining accident records (Fang et al., 2004). Maintaining accident records in organizations helps to know about the nature of accidents, its prevention and effectiveness of occupational safety and health management system (Probst et al., 2008; De Silva et al., 2018) and this is seriously taken into consideration so as to prevent the recurrence in the near future. Nevertheless, there have been difficulties in maintaining accident records in construction sites due to contractors' belief that it is bad for business and lacks safety culture (Afolabi et al., 2016). However, organizations that have acquired and implemented OHSAS certification shall keep and maintain records as required by OSHAS 18001:2007 guidelines (OHSAS, 2007; De Silva et al., 2018). Organizations with good safety management system facilitate the requirement of adequate safety culture in organizations (Remawi et al., 2011; Bahn, 2013). Also, it is observed that, in certified organizations, safety culture programs are often endorsed or imposed by regulatory authorities and have been developed and implemented to prevent recurrence of these or similar consequences.

6.5.3.2 Important aspects of cultivating good safety culture in organizations

Interviewees were asked about their perceptions of safety culture and key aspects of construction organizations that could foster a good safety culture. Details are summarized as:

Case 1 described safety culture as: *"Safety culture is viewed as the top agenda in any organization and rest follows……. The important aspect of safety culture is that safety begins with everyone [individual] in the organization and leads to oneness in achieving safety goals. Safety culture at the project level reduces accidents [accident and incident rates] which ultimately minimizes accident cost.*

On the basis of its importance in organizations: "….. *safety culture is continuous performance of safe practices in any organization….. important aspects that can cultivate a good safety culture is by recognizing occupational hazards, complying, communicating, demonstrating and caring about occupational health and safety issues."* [Case 3]

Practical consideration of safety culture is regarded as: "*Safety culture can be regarded directly to worker's loyalty, keeping the job-site up and running, and an improved risk profile. Good and positive safety culture is a key feature of a supportive working environment of any organization."* [Case 2]

The benefit of recognizing safety culture as one of the key aspects is viewed as: "*In my opinion, embracing safety as a fundamental company value and worker involvement in job site safety is safety culture. Communication and coordination related to safety tasks reduce accidents and fatalities among employees and thus create a good safety culture in organization."* [Case 4]

Although, these construction organizations did not actively use the word "safety culture", the term "safety culture" was even viewed as an abstract one and they had different ideas on the term "safety culture" and "overall safety" in particular. Interviews perceived safety culture to be emphasized with openness and transparency of safety-related issues at construction projects and it was reported that safety culture was measured on the basis of standards and enforcement of rules and regulations; especially

in certified organizations. Based on these interviewees, practical safety problems are described as components of safety culture, such as safety of working conditions, well-defined procedures, and workplace safety. Some of the aspects that is believed and are required to cultivate good safety culture are: management commitment (Fernández-Muñiz et al., 2012; Rajaprasad and Chalapathi, 2015; Ghahramani, 2016; Ghahramani and Salminen, 2019), standard operating procedures (Fernández-Muñiz et al., 2012; Venkata-Siva-Raja-Prasad et al., 2013; Koivupalo, 2015), incentive Programs (Vinodkumar and Bhasi, 2011; Mohammadfam et al., 2017), training programs (Venkata-Siva-Raja-Prasad et al., 2013; Rajaprasad and Chalapathi, 2015; Ghahramani, 2016; Hrenov et al., 2017; Wen Lim et al., 2018; Escorcia et al., 2018), strict implementation of policies and procedures (Hohnen and Hasle, 2011; Fernández-Muñiz et al., 2012; Koivupalo et al., 2015; Wen Lim et al., 2018). Nevertheless, traditional safety management systems (used by non-certified organizations), do not always increase safety outcomes as they focus solely on technical requirements and only on achieving short-term outcomes (Weinstein, 1996). Ultimately, safety was seen as a problem for everyone and a responsibility that requires everyone's attention.

6.5.3.3 Importance of knowledge management strategies to improve safety culture

Next, the interviewees representing different cases were asked about the importance of knowledge management strategies that facilitates or supports safety management practices at construction organizations.

Case 1: "……*knowledge is the domain which capture's the readiness and eventuality gears up to take up future challenges. Knowledge management implies the development of new tasks which are performed by members of all organization levels so as to improve safety of an organization."*

Case 2: "*everyone in the organization is responsible for safety and made aware of safety protocols which seemingly aims for continuous improvement. So, knowledge management strategies would be very essential to avoid repetitive mistakes. Even a small mistake in safety implementation would have a larger impact."*

Further, Case 4 claims that "*employees involved in health and safety activities are more concerned about safety issues and thus be able to learn and share knowledge regarding safety aspects in the company."*

Importance of knowledge management strategies not only addresses employees' behaviour, practices and standards, but also reflects on the role of management within the organization that provide an atmosphere to facilitate and enable a safe working environment through which safety culture can be incorporated into organizational practice (Jarvis et al., 2014). In this regard, the requirement of a positive safety culture acts as a primary attribute of a positive working environment in which workers engage in health and safety programs, and thus they feel more comfortable raising concerns regarding safety problems, sharing knowledge, and learning through imitation and participation (Haukelid, 2008). This positive culture requires a special organizational structure that allows direct communication, initiates mutual learning and allows people to exchange (tacit and explicit) knowledge directly (Valler and Virovere, 2010). The organization's systems, people involved, and technologies must be integrated as a management system in order to achieve efficient and quick flow of information and knowledge related to safety and thereby necessitates evolving as a knowledgeable organization (Jarvis et al., 2014). Therefore, strong safety culture in the company prevails when it adopts an effective safety management system. This can be accomplished by ensuring regular safety training and provision of appropriate safety information at the right time for employers and employees (Jarvis et al., 2014). These results are in line with Merill (2008), suggesting that "an effective management system enables organizational innovation, and this is achieved through the exchange and flow of knowledge between people." In addition, an active knowledge management system is needed for achieving shared and common goals, attitudes, and understanding among all employees (Järvis et al., 2016). This was supported by the fact that issues and views on lessons learned were shared, and mutual help was sought among employees and flow of relevant information was considered as improvement strategies that support the development of safety culture in construction organizations.

Moreover, OSHAS 18001:2007 certification is considered to be an effective tool to improve occupational health and safety in construction organizations (Fernández-

Muñiz et al., 2012; Rajaprasad, and Chalapathi, 2015). However, non-certified companies claim that they follow safety rules, guidelines, and regulations that are formulated within their company. And these organizations believe that safety certification involves a number of changes and enhancements in their current safety procedures and is therefore difficult to adapt or implement it in the current state. Another possible reason is that most of these organizations do not have the necessary resources, such as economic, human resources, expertise, and technology, to adopt and enforce workplace safety and health practices as needed by OSHAS 18001:2007 requirements.

6.5.3.4 Barriers to adopt or implement knowledge management strategies for developing safety culture

In this regard, interviewees were asked which factors they believe are hindering implementation of knowledge management strategies for improving safety culture in construction organizations. Details are summarized as:

Case 1: *"A deeper systematization of operational tasks related to safety [safety roles and responsibilities], well-defined communication channels, greater coordination, and control mechanism at all operational levels of safety……"*

Case 2: *"Training, regular safety briefings, and open communication within the organization."*

Case 4: *"Well-defined organization structure and proper interactions among stakeholders focusing towards achieving a common competitive goal are the barriers towards implementing knowledge management strategies for developing safety culture in construction organizations."*

These responses which the interviewees perceive are the factors they saw as vulnerable or issues that should be facilitated in future. Among them, lack of communication channels and improper safety training programs were most commonly mentioned as a barrier to safety improvements. This was mainly attributed to communication problems, differences in working environment, working standards and procedures that lack in fulfilling responsibilities assigned to individuals at the workplace. Other issues were;

systematization of tasks related to safety, ineffective safety roles and responsibilities, improper coordination and control, ineffective management commitment, increase in paperwork, irregular safety briefings, excessive requirements of certification and unorganized organization structure. Non-certified organizations believe that there was a weak reporting system that prevented improvement in safety management. And, reporting was deemed to be laborious and the threshold was too high for regular updating. They believe and claim that without monitoring or documentation, corrective actions had been enforced in the organization through appropriate channels.

Furthermore, interviewees were then asked which factors enabled or promoted safety improvements that support the implementation of knowledge management strategies for improving safety culture in construction organizations. Respondents indicated that, there is need for an effective open-discussion of safety-related issues that initiates discussion on facts pertaining to issues and provides views on lessons learned, and supports seeking mutual help and flow of information; these factors were considered to improve safety and thus develop positive safety culture in construction organizations (Teperi et al., 2019). Training and competence among employees is also perceived as supporting factor for safety improvement which indicates an eagerness to share views and express an opinion as a result of an improvement in level of competence. Following factors have also been pointed out as supporting factors; a strong culture in the organization with committed senior management level dedicated to changes in general; safety as a part of all processes and resources, rules and regulations that will be available if something has to be changed. Lastly, key personnel interviewed also reported strengths and best practices, such as teamwork, mutually sharing work experience, post-accident discussions.

6.5.4 Summary of interview analysis

The interviews are aimed at gaining in-depth insights into individual perceptions of safety culture and to know the importance of knowledge management strategies and in ways to improve safety culture in construction organizations. The process of gaining an in-depth understanding of knowledge-based safety culture involved one-to-one interviews with professionals from both OHSAS 18001:2007 certified and non-

certified construction organizations. Quite certainly, there were differences in the nature of working conditions and environment in both scenarios. These discrepancies are partly expressed in the outcome of the interviews. While different groups perceive safety issues slightly different, yet results showed some commonality. In consideration of this, summary of key results was further utilized to formulate an improvement framework for safety culture in construction organizations. Findings also revealed that; the formulated assessment framework was easy to implement in these aforementioned organizations. Hence, this evaluation is believed to be a more comprehensive framework for evaluating knowledge-based safety culture practices in construction organizations.

6.6 IMPROVEMENT FRAMEWORK FOR OVERALL SAFETY CULTURE

A better understanding of safety culture divergences between different working levels is required to strengthen and improve safety records which are considered to be poor in construction organizations (Pungvongsanuraks and Chinda, 2010). Moreover, safety culture must be considered in order to reduce the number of accidents and improve safety records (Dester and Blockley, 1995) and therefore a more comprehensive framework for evaluating knowledge-based safety culture practices in construction organizations is required.

Proposed improvement framework presented in Figure 6.3 covers the current state of safety culture conception in construction industry; highlights the benefits and drawbacks of key knowledge management strategies; also shows hindering and supporting factors for improvement of overall safety culture; and, lastly, suggestions for development needs that are described from the study analysis.

Since the implementation of the standards, procedures, and guidelines as proposed by OHSAS 18001:2007 is intended to encourage safety culture in construction organizations, we assumed that the experiences of the interviewees would show us important signs of the type of safety culture that existed and how this safety culture could be defined. This study showed that in construction organizations, the idea of safety culture is not widespread. Safety culture was considered abstract, and the conceptions of the interviewees appeared ambiguous and fragmented. In summary,

safety culture has been seen as a certain way of behavioural actions on safety issues; recognizing and appreciating safety operations in everyday work and thus being able to work in a safe workplace. Furthermore, safety culture is believed to be a part of overall culture of an organization. Safety is therefore regarded as one of the key core beliefs of the organization and thus indicating the importance of safety implementation in organizations.

The interviewees often emphasized safety compliance with safety culture principles and guidelines. Although the involvement of technology and procedures dominated the interviewee's conceptions i.e., role of explicit knowledge management types; the role of tacit knowledge was clearly not the focus. Moreover, it is the focus of the management to encourage safe behaviour of the employees (Frazier et al., 2013; Teo and Feng, 2009) that is necessary if tacit knowledge is to be converted into explicit shared knowledge (Jarvis et al., 2014).

One of the main drawbacks of knowledge-based safety culture practices for employees was inadequate resources of the main safety motivators. Provision of adequate knowledge and training on safety issues, as well as routine safety checks as required by law, and can therefore be viewed as a dedication on the part of management, and it is believed that deficiencies in these safety issues represent the company's safety culture (Teperi et al., 2019). Furthermore, if the employer fails to comply with safety guidelines, it is reasonable to assume that workers may not necessarily be able to do their work safely. Some of the key issues concerning practices are; requirement of specialized organization structure, resources such as financial, manpower, key knowledge areas, and technology for effective implementation and maintaining knowledge-based safety culture strategies.

Next, the investigation was done to know how familiar interviewees were with and considered important the knowledge-based safety culture practices in construction organizations. It was found that their considerations of the important practices indicated which safety culture factors were central in influencing the prevailing safety culture of organizations. Among them are; open discussion of safety-related issues (Teperi et al., 2019), training and competence (Fernández-Muñiz et al., 2012; Marhani et al., 2013;

Mohammadfam et al., 2017; Simukonda et al., 2018; Wen Lim et al., 2018), commitment of top management (Fernández-Muñiz et al., 2012; Rajaprasad and Chalapathi,2015; Ghahramani, 2016; Ghahramani, and Salminen, 2019), safety being part of activity and resources (Teperi et al., 2019), teamwork and mutual knowledge sharing (Pheng and Pong, 2003; Teperi et al., 2019). These factors were repeatedly mentioned as knowledge-based safety culture practices.

The interviewees were then asked, what they saw as factors that hinder safety progress in order to better understand the development needs of knowledge-based safety culture practices. Although they acknowledged that the foundation of safety management systems to be a robust reporting system, they felt that this kind of effective reporting system was lacking and slight deviations were not reported. It was thus regarded that openness and participation should be increased for effective knowledge sharing mechanisms in construction organizations. Open discussions, exchange of information, individual's perspectives on lessons learned, recognition of mutual assistance, and information flow are factors that facilitated safety improvements (Teperi et al., 2019). Training and competence were also seen as supporting factors; with this, the level of competence increased as well as the desire to share observations and raise opinions as a result of this enhanced competence (Marhani et al., 2013; Mohammadfam et al., 2017; Simukonda et al., 2018; Wen Lim et al., 2018). Systematic management, pro-activeness and implementation of safety plans have also been identified as functional factors of safety culture. Organizations with positive safety culture include workers who understand that things can go wrong, accept that errors occur, identify failures and have the ability to learn and take corrective measures to avoid their recurrence (NPSA, 2004).

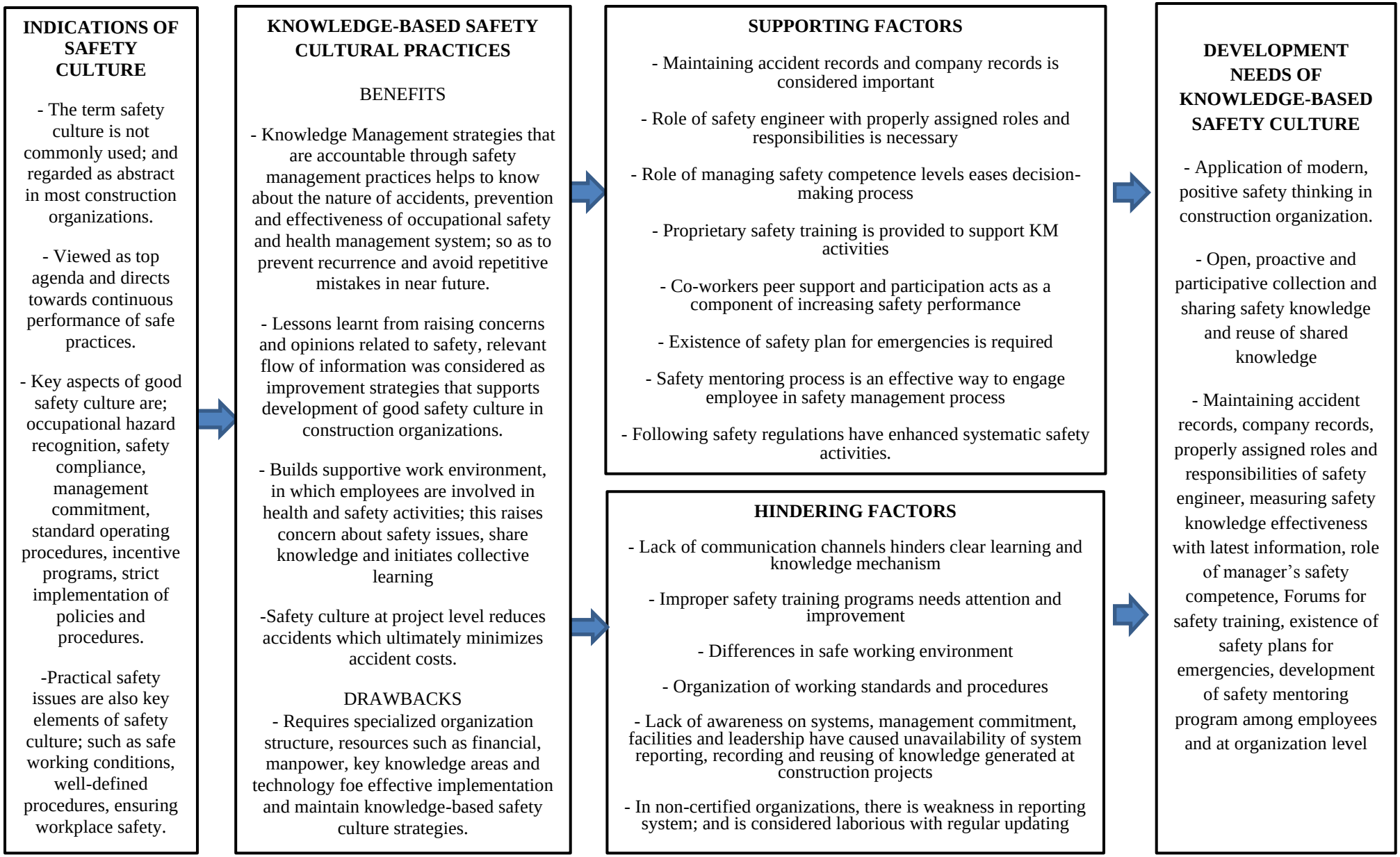


Figure 6.3 Improvement framework of overall safety culture

The ability to identify, react, raise opinions and learn from adverse events is an important component of creating a positive safety culture in organizations (Benn et al., 2009; Allen et al., 2010). Although the dissemination of information and knowledge about safety is essential for efficient and effective organizational health and safety management; however, little attention was paid to the process of the safety knowledge exchange. Effective management of this safety-related information and knowledge within the organization requires proper dissemination (Nuñez and Villanueva, 2011). Therefore, it is suggested that organizations to develop a positive safety culture and in order to improve employee's safety behavior organizations must give more attention to managing their safety knowledge (i.e., how knowledge is developed, distributed, shared and re-used by employees) (Jarvis et al., 2014). All the factors revealed suggested that there is an increase in motivation and competence to strengthen safety culture of construction organizations and it is, therefore, important to reinforce these factors in the future.

6.7 CHAPTER SUMMARY

Summary of main findings of quantitative analysis (assessment framework) and qualitative analysis (interviews) are utilized to develop improvement framework for overall safety culture of construction organizations. This also verifies the results of MANOVA analysis and to uncover the difference in perceptions of employees in certified and non-certified organizations. Although the assessment framework showed the importance of knowledge-based safety culture factors and its evaluation criteria on the level of safety culture, interviews provided further information on barriers to adapt or implement knowledge management strategies for safety improvement. Moreover, the interview findings closely mirror the quantitative research results. This has been utilized to justify the perception difference of individuals from both certified and non-certified organizations. Then, the comparison of safety culture scores was made between these organizations. Based on these results, it can be concluded that re-use and effective utilization of knowledge gained from previous projects related to safety was the most frequently mentioned area for safety improvement. Results of the analysis indicated that knowledge management strategies

were identified to warrant improvement on overall safety culture in construction organizations. Factors that are identified as key aspects of overall safety culture are believed to in turn affect safety performance. Interviews also revealed the importance of knowledge management strategies that are required to overcome potential barriers that can be integrated as a signal of a new, positive knowledge-based safety culture in construction organizations. Combination of data arising from interviews supported the results of the survey and provided insights as to how knowledge-based safety culture was perceived in different case scenarios of construction organizations.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

The chapter concludes the research findings of all objectives of the study, and suggests improvements strategies for enhancing safety culture in construction organizations. It also presents theoretical and practical implications of the study, limitations of the study, and highlights future research directions.

7.2 REVIEW OF RESEARCH OBJECTIVES AND MAJOR FINDINGS

Safety culture study is essential and necessary as it is a part of organizational culture and focuses on improving safety aspects of the organization. Many organizations, including construction industry have shown greater attention towards facilitating safety culture as a means to decrease accidents, incidents, and risks occurring at the workplace. For effective implementation of safety management practices, organizations tend to set safety culture as a significant factor for enhancing occupational health and safety at the workplace. This created the potential to explore the recent trends in safety culture research. But, the amount of literature available on this topic makes it challenging for practitioners and researchers to have a structured outline of the topic. So, this study made an attempt to provide essential concepts of safety culture research in construction industry by providing suitable realistic evidence and theoretical developments. This study explored how researchers have defined and measured safety culture to predict and justified occupational health and safety outcomes in construction industry. The information provided gave a clear representation on the topic of safety culture and as this can help researchers and practitioners for recognizing critical influences from articles of safety culture research topics. Careful examination of safety culture research topics provided insights on various constructs of

safety culture studies till date and present trends and issues towards creating a safe operational environment in construction industry were explained.

Based on a thorough review of literature, the importance of knowledge management that enables professionals and discipline experts to share collective data from lessons learned, adopt best practices, and collaborate on real-time issues are ignored. Up until now, there has been no study that focuses on the influence of knowledge as a key dimension to improve safety culture in construction industry; existing safety culture theories and models solely focus on addressing three dimensions (i.e., psychological, behavioural and organizational). Studies on integrating knowledge management practices in safety culture aspects have been rarely conducted before. Organization's safety management capability and maturity can be increased through knowledge that is gained through safety task assessment and when its implementation is recorded and applied to future projects. In other words, organizations can apply knowledge management strategies and feedback mechanisms to close the loop of safety management process by disseminating knowledge gained from each project and be able to improve safety knowledge and performance on future projects. This necessitated a means to identify critical contributary knowledge-based safety culture factors relevant to construction industry. The first objective of this research was concluded by identifying the key factors, formulating the conceptual framework and developing hypotheses to understand the impact of knowledge-based safety culture in construction industry.

Second objective of this study was achieved by analyzing the survey responses of the measurement instrument to assess the relevance of identified factors for construction industry and evaluate the degree of interdependency of the identified factors. Need to understand the level of safety culture based on most relevant factors was assessed by developing a questionnaire-based survey instrument and applied it to an industrial setting, i.e., Indian construction industry. The use of safety culture surveys, in this study the use of 'knowledge-based safety culture measurement instrument' measures cultural aspects of safe working environment by measuring the contributory factors of safety culture.

Development of knowledge-based safety culture survey instrument relevant to construction professionals provides a means to identify critical factors among different stakeholders and ultimately provide a benchmarking mechanism to compare the level of safety culture in construction projects. Also, the developed survey instrument to assess safety culture provides a pragmatic approach for construction project managers to evaluate the effectiveness of their safety management practices and identify the effort needed from a specific safety agent for improvement of safety. The outcome of this study could be utilized to configure targeted safety practices and enhance the overall safety performance of construction industry. This developed questionnaire is used as a measurement tool to assess safety culture among individuals operational in Indian construction industry. Data collection and analysis measured with the proposed 69-factor questionnaire survey presents evidence that employee perception in Indian construction setting can be consistently measured through this survey instrument. Finally, the instrument was utilized in a sample of construction projects to gauge the advantages of utilizing the survey results to additionally enhance the legitimacy of the outcomes. Further, if used as a proactive measure of safety management, it provides an appropriate tool for measuring safety before an incident or fatality occurs.

The third objective was concluded by formulating an assessment framework for evaluating overall safety culture in construction industry. Improvements that could inevitably contribute to continuous monitoring and reviewing safety culture in an organization are necessary for construction organizations. In order to achieve this, a safety culture quantitative assessment framework is required. This comprehensive framework takes into account the most pertinent factors relevant to construction industry. The factors considered in formulating the assessment framework are based on their importance towards improving safety culture in an organization. The results of the questionnaire survey are used to develop the framework. Different case scenarios were considered to validate the assessment framework and conclusions were drawn based on the findings. However, the use of questionnaire survey alone cannot capture broader influences of the impact of safety culture on individual's perception of safety culture in construction organizations. Hence,

semi-structured interviews were conducted to review better understanding of factors that affect overall safety culture in construction organizations.

7.3 THEORETICAL IMPLICATIONS

Safety culture plays an important role in enhancing safety performance and thereby reduces the risk of unsafe behavior of individuals at construction projects. Therefore, exploring safety culture dimensions with its contributory factors and measuring it effectively can improve safety culture in construction organizations. The study has contributed to providing theoretical implications in following aspects:

- Systematic literature review on the topic of safety culture provides reviews the recent trends and an overview of this topic. This review is believed to encourage further research on safety management aspects in construction industry.
- Results of this study revealed that the use of mixed-methods to study safety culture can provide a multifaceted 'bigger picture' of the process of safety culture and its phenomena, which is not possible using a single method. Findings of this study do provide evidence of the benefit of mixed-method approach including survey-based approach, formulation of assessment framework with semi-structured interviews when examining safety culture in construction organizations. Undertaking research in this way does require engagement, and commitment of study respondents under consideration to provide reliable data for the study and suggest improvement strategies.
- This study contributes to the current safety literature by developing a valid and reliable measurement instrument consisting of factor structure of knowledge-based safety culture of construction organizations. This measurement scale developed consists of four critical dimensions of safety culture; namely, psychological, behavioural, organizational and knowledge dimensions with 69-contributary factors. This measurement scale demonstrated high validity and reliability in the Indian context. By providing a uniform measuring criterion, this measurement scale will facilitate future safety management literature related to safety culture. The creation of a measurement scale that is designed on a strong theoretical basis and pointedly analyzes cultural

aspects of the organization would be extremely valuable. The management can then use the metric to obtain a holistic understanding of the state of companies own organizational culture. This is important, especially when assessing cultural aspects in relation to safety, as the consequences of a poor safety culture may be severe. Further, the model proposed and validated in this setting could serve as the theoretical basis to provide a better understanding of workers' safety behaviours. This insight will assist construction organizations to strategically focus their efforts to ensure the success of safety. Also, this study contributes to the promotion of safety theory in Indian construction industry and provides practical implications for construction enterprises when they engage in improving safety conditions in their organizations.

7.4 PRACTICAL IMPLICATIONS

Safety culture is a crucial factor that helps various stakeholders of construction organizations to reduce the level of accidents and injuries in construction projects. Responsibility of all employees is to improve safety in construction projects by understanding the importance of information and knowledge pertaining to safety hazards and to develop a positive safety culture that makes safety the concern of every individual of the organization.

The study provides insights into safety management practices of construction industry. Practical implications include following aspects:

- Effective survey-based measuring instrument derived from this study is a comprehensive tool suited for construction organizations. It can be used to examine the perceptions of individual's operational in construction organizations. The measurement tool developed predominantly focuses on considering the importance of knowledge management in enhancing safety culture of the construction industry. This instrument can be utilized to compare the level of safety culture among key stakeholders of construction projects. This measurement tool also serves for benchmarking cultural aspects of safe working system within an organization; thus, can boost overall safety

in the industry as a whole. Moreover, with reasonable modifications, this measurement instrument could be used in other industries to be able to improve safety performance.

- The motivation for this study contributes to the development of practitioner's measurement tool to assess cultural aspects of the work system. Effective implementation of knowledge management strategies in relation to safety culture which can be assessed through the formulated assessment framework may serve as a predictor or proxy tool that would provide project managers and employees with rich feedback to determine the strengths and weaknesses in safety management practices and thereby encourage organizations to improve in these areas. The assessment framework proposed in this research is a simple-to-administer and comprehensive tool for measuring knowledge-based safety culture practices in construction organizations; this measurement approach enables construction companies to continuously monitor and improve their performance with respect to occupational health and safety issues.
- Implications of assessment framework formulated from this study can be considered as an assessment tool, by which the current situation of construction organizations with regard to safety culture can be figured out; and, the most significant factors attributing to this situation can be determined; and finally, corrective actions can be taken based on the previous steps. The absence of these factors is likely to limit the practicality of this approach in industrial settings. This framework synthesizes information across fragmented conceptualizations to clearly depict the dynamic nature of safety culture and specific drivers of its development. This evaluation framework could be utilized to assist decision-makers in several ways; including increase in tendering opportunities, discounted insurance premium, categorizing objective wise grading to award or sanction of project, and to determine any deviations from the best practices by benchmarking performance and to ensure continuous improvement.

7.5 LIMITATIONS OF THE STUDY

There are certain limitations to the present study. First, the study adopts a cross-sectional approach to collect and analyze the survey data. Second, the study proposes that the data

collected from the survey is largely contributed by large-sized companies (48.1%). However, the remaining responses is contributed by medium (5.2%) and small sized-companies (46.7%). Among the small-sized companies, there were responses including micro-companies (employees less than ten). These small-sized companies have a very different culture which is prevalent and has a very different approach is required to manage and improve occupational safety. Also, these small-size companies do not generally contribute to shaping safety culture with effective knowledge exchange and therefore, do not necessarily contribute toward organization learning process. Third, the scope is limited to registered members of the indexed construction companies. Fourth, the evaluation of assessment framework by using safety culture scores accounts from an individual's perspective of the organization. However, this can be better representable with many individuals of the same organization to obtain a more relative safety culture score of any organization. Also, care should be taken while extrapolating the results by survey instrument and assessment framework to other cultures, regional settings, and other developing countries. Despite these limitations, the study has revealed certain important implications concerning both theoretical and practical significance.

7.6 FUTURE RESEARCH DIRECTIONS AND RECOMMENDATIONS

This research offers a valuable starting point for future safety interventions regarding safety culture aspects of construction organizations. Future research should focus on replicating the study findings through longitudinal data. Factors considered in this research can be further tested for their effectiveness toward implementation in similar such construction organizations. This would highlight the positive and negative characteristics of organization safety culture. The measurement tool can be further validated by comparing the perspectives of key stakeholders across construction projects. The use of document analysis as part of determining safety culture needs to be examined in more detail. Further scope can focus on actionable factors. This would require practical frameworks, tools for safety experts, and management by regulatory bodies. It is highly recommended to utilize this systemic method for other future safety culture research.

By encouraging organizations to integrate these competencies into their existing practices, it should be possible to; (1) educate the industry as to best practice in safety management aspects, (2) provide a safety culture management system that allows a good safety culture to be built quickly on new projects, (3) ensure a standard level of competency within the workforce to allow for ease of understanding standard working procedures and (4) improve safety culture and in turn potentially improve safety performance.

Furthermore, even when a proficient safety culture is present, the knowledge about how to develop and maintain this culture is often lost when the project ends and the workers disband. Hence, a new system is required that facilitates the rapid development of a positive safety culture when a project begins and helps to maintain this culture even when the workforce is changing.

Consequently, a safety culture management approach in this particular industry requires some degree of standardization of competencies as well as uniform training packages to reduce the need for construction organizations to be constantly retraining new workers. To utilize a safety culture approach to safety management practices, construction industry needs to adopt a system that can overcome the transitory nature of the work and the workforce. At the organization level, organizations could play an even more proactive role in supporting employees at operational level by highlighting local knowledge and work-as-done. This could be effectively implemented through continuous effort to regularly monitor and review cultural aspects of safety in an organization. At the project level, clear understanding of work process and development needs of personnel operational that includes recent safety issues are made visible and put into practice. At individual level, good competence, responsibility, reporting culture and activeness towards safety issues should be promoted by both project and organization levels.

Suggestions to improve safety culture in the work process are ensured by some specific requirements for structural prerequisites of safety culture. These structural prerequisites are organizational processes, procedures or other institutionalized methods that aim to

influence safety culture. Steps to increase safety culture that involve all levels of the company both from top management to project workers are;

- Safety is currently more often managed in a top-down approach than bottom-up manner. In general practice, bottom-up workplace interventions should be conducted which take into account the local knowledge of the operative personnel in decision-making and everyday work. There is a need for a strong commitment from the top management of companies to be able to continue to conduct the evaluation and improvement of the implementation of work safety regulations.
- Documenting the frequency, methodology, and resources assigned to safety culture follow-up, including a periodic follow-up report, and for regular independent assessment and self-assessment of safety culture. Reporting channels for employees' safety concerns and safety initiatives, including the possibility for anonymous reporting. As the weaknesses of proper reporting systems and communication channels have long been prevalent phenomena in construction organizations, it is recommended that a new kind of positive safety thinking is needed; one that utilizes effective mechanisms to support the improvement of safety culture through knowledge management strategies.
- There is a requirement of nominating a safety culture coordinator or manager with the resources and authority to carry out safety culture work. Essential monitoring for any accidents at work needs to be evaluated regularly and continuously to improve the implementation of work safety. Also, in this regard, careful planning of the budget allocation on safety is essential that concerns adequate safety-training programs. Moreover, there is a need for training to know what to do in case of accidents or incidents.
- The code provision of adopting OHSAS 18001:2007 in construction organizations could be applied to modern safety thinking that consists of proactive, systematic and participative cooperation and learning processes that focus on human-related issues and work-as-done. Moreover, there is a need for appropriate policies that include rewards

and punishments so that the implementation of working safety can be done well and can be understood by all employees and workers.

7.7 CHAPTER SUMMARY

This chapter has summarized the review of research objectives and highlights the importance and significance of major findings of the study. It also elucidated the theoretical, practical implications, and highlighted limitations of the study. Future research directions and suitable recommendations were offered at the end.

REFERENCES

Abad, J., Lafuente, E., and Vilajosana, J. (2013). "An assessment of the OHSAS 18001 certification process: Objective drivers and consequences on safety performance and labour productivity." *Safety Science*, 60, 47-56.

Abbe, O.O., Harvey, C.M., Ikuma, L.H., Aghazadeh, F. (2011). "Modelling the relationship between occupational stressors, psychosocial/physical symptoms and injuries in the construction industry." *International Journal of Industrial Ergonomics*, 41(2), 106-117.

Aboagye-Nimo, E., Raiden, A., King, A., and Tietze, S. (2015). "Using tacit knowledge in training and accident prevention." *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, 168(5), 232-240.

Abowitz, D.A., and Toole, T.M. (2010). "Mixed method research: Fundamental issues of design, validity, and reliability in construction research." *Journal of Construction Engineering and Management*, 136(1), 108-116.

Afolabi, A.O., Tunji-Olayeni, P.F., Amusan, L.M., Omuh, I.O., Ojelabi, R.A., and Oyeyipo, O. (2016). "Safety cultured industry through the integration of occupational health and safety (OHS) courses in the built environment curriculum." *INTED-2016 Conference*, 5811-5821.

Agumba, N.J., and Haupt, C.T. (2014). "The implementation of health and safety practices: Do demographic attributes matter?." *Journal of Engineering, Design and Technology*, 12(4), 530-550.

Ajslev, J., Dastjerdi, E.L., Dyreborg, J., Kines, P., Jeschke, K.C., Sundstrup, E., and Andersen, L.L. (2017). "Safety climate and accidents at work: Cross-sectional study among 15,000 workers of the general working population." *Safety Science*, 91, 320-325.

Akdeniz, B., Giderler, C., and Özler, E.N.D. (2018). "Can other disciplines support occupational health and safety efforts? Importance of safety culture: A study on a coal mine Institution." *Acta Academica Karviniensia*, 18(4), 5-16.

Akroush, N.S., and El-adaway, I.H. (2017). "Utilizing construction leading safety indicators: Case study of Tennessee." *Journal of Management in Engineering*, 33(5), 06017002.

Allen, S., Chiarella, M., and Homer, C.S. (2010). "Lessons learned from measuring safety culture: An Australian case study." *Midwifery*, 26(5), 497-503.

Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R. (2002). "Quantitative and qualitative research in the built environment: Application of mixed research approach." *Work Study*, 51(1), 17-31.

Ankrah, N.A. (2007). "An investigation into the impact of culture on construction project performance." Unpublished PhD thesis submitted to School of Engineering and the Built Environment, University of Wolverhampton, UK.

Antonsen, S. (2009). "Safety culture: Theory, method and improvement." CRC Press, Ashgate Publication Company, London.

Arboleda, C.A. and Abraham, D.M. (2004). "Fatalities in trenching operations: Analysis using models of accident causation." *Journal of Construction Engineering and Management*, 130(2), 273-280.

Arcury, T.A., Mills, T., Marín, A.J., Summers, P., Quandt, S.A., Rushing, J., and Grzywacz, J.G. (2012). "Work safety climate and safety practices among immigrant Latino residential construction workers." *American Journal of Industrial Medicine*, 55(8), 736-745.

ASCNI (Advisory Committee on the Safety of Nuclear Installations), (1993). "Third report: Organizing for safety." ACSNI Study Group on Human Factors. London: HMSO, U.K.

Awodele, A.O. (2012). "Framework for managing risk in privately financed market projects in Nigeria." Unpublished PhD thesis submitted in fulfilment of the degree of Doctor of Philosophy in Construction Project Management to School of the Built Environment, Heriot-Watt University, UK.

Azhar, S., and Choudhry, R. (2016). "Capacity building in construction health and safety research, education, and practice in Pakistan." *Built Environment Project and Asset Management*, 6(1), 92-105.

Bahari, S. F., and Clarke, S. (2013). "Cross-validation of an employee safety climate model in Malaysia." *Journal of Safety Research*, 45, 1-6.

Bahn, S. (2012). "Moving from contractor to owner operator: Impact on safety culture–a case study." *Employee Relations*, 35(2), 157-172.

Bahr, N.J. (2018). "System safety engineering and risk assessment: a practical approach." CRC press.

Bandura, A. (1977). "Self-efficacy: Toward a unifying theory of behavioural change." *Psychological Review*, 84(2), 191.

Bandura, A. (1991). "Social cognitive theory of self-regulation." *Organizational Behaviour and Human Decision Processes*, 50(2), 248-287.

Benn, J., Koutantji, M., Wallace, L., Spurgeon, P., Rejman, M., Healey, A., and Vincent, C. (2009). "Feedback from incident reporting: Information and action to improve patient safety." *BMJ Quality and Safety*, 18(1), 11-21.

Biggs, H. C., and Biggs, S.E. (2013). "Interlocked projects in safety competency and safety effectiveness indicators in the construction sector." *Safety Science*, 52, 37-42.

Biggs, H.C., Dinsdag, D., Kirk, P.J., and Cipolla, D. (2010). "Safety culture research, lead indicators, and the development of safety effectiveness indicators in the construction sector." *International Journal of Technology, Knowledge and Society*, 6(3), 133-140.

Biggs, S.E, and Banks, T.D. (2012). "A comparison of safety climate and safety outcomes between construction and resource functions in a large case study organization." *Occupational Safety in Transport Conference.* Gold Coast, Australia, 1–6.

Biggs, S.E., Banks, T.D., Davey, J.D., Freeman, J.E. (2013). "Safety leaders' perceptions of safety culture in a large Australasian construction organization." *Safety Science*, 52, 3-12.

Blaxter, L., Hughes, C. and Tight, M. (2006). "How to research (3rd ed.)." England: Open University Press.

Booth, A., Sutton, A., and Papaioannou, D. (2016). "Systematic approaches to a successful literature review." SAGE Publications Ltd., Thousand Oaks, CA, United States.

Booth, R.T., and Lee, T.R. (1995). "The role of human factors and safety culture in safety management." *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 209(5), 393-400.

Borys, D. (2012). "The role of safe work method statements in the Australian construction industry." *Safety Science*, 50(2), 210-220.

Boyd, B.K., Finkelstein, S., and Gove, S. (2005). "How advanced is the strategy paradigm? The role of particularism and universalism in shaping research outcomes." *Strategic Management Journal*, 26, 841-854.

Braithwaite, J., Westbrook, M.T., Iedema, R., Mallock, N.A., Forsyth, R., and Zhang, K. (2005). "A tale of two hospitals: Assessing cultural landscapes and compositions." *Social Science and Medicine*, 60(5), 1149-1162.

Brondino, M., Pasini, M., and da Silva, S.C.A. (2013). "Development and validation of an integrated organizational safety climate questionnaire with multilevel confirmatory factor analysis." *Quality and Quantity*, 47(4), 2191-2223.

Burt, C.D., Sepie, B., and McFadden, G. (2008). "The development of a considerate and responsible safety attitude in work teams." *Safety Science*, 46(1), 79-91.

Cambraia, F.B., Saurin, T.A., and Formoso, C.T. (2010). "Identification, analysis and dissemination of information on near misses: A case study in the construction industry." *Safety Science*, 48(1), 91-99.

Cesarini, G., Hall, G., and Kupiec, M. (2013). "Building a proactive safety culture in the construction industry." 12 steps to a safer job site. Ace Construction Company, Philadelphia, PA - United States.

Chan, A.P., Wong, F.K., Chan, D.W., Yam, M.C., Kwok, A.W., Lam, E.W., and Cheung, E. (2008). "Work at height fatalities in the repair, maintenance, alteration, and addition works." *Journal of Construction Engineering and Management*, 134(7), 527-535.

Chen, L., and Mohamed, S. (2000). "Impact of organizational cultural factors on knowledge management in construction." *Joint International Conference on Construction, Culture, Innovation and Management (CCIM)*, Dubai.

Chen, P., Partington, D., and Wang, J.N. (2008). "Conceptual determinants of construction project management competence: A Chinese perspective." *International Journal of Project Management*, 26(6), 655-664.

Chen, P., Partington, D., and Qiang, M., (2009). "Cross-cultural understanding of construction project managers' conceptions of their work." *Journal of Construction Engineering and Management*, 135(6), 477-487.

Chen, Q. and Jin, R. (2012). "Multilevel safety culture and climate survey for assessing new safety program." *Journal of Construction Engineering and Management*, 139(7), 805-817.

Chen, Q., and Jin, R. (2011). "Safety4Site commitment to enhance jobsite safety management and performance." *Journal of Construction Engineering and Management*, 138(4), 509-519.

Chen, Q., Jin, R., and Soboyejo, A. (2013). "Understanding a contractor's regional variations in safety performance." *Journal of Construction Engineering and Management*, 139(6), 641-653.

Cheng, C.W., and Wu, T.C. (2013). "An investigation and analysis of major accidents involving foreign workers in Taiwan's manufacture and construction industries." *Safety Science*, 57, 223-235.

Chin, W.W. (1998). "The partial least squares approach to structural equation modeling." *Modern Methods for Business Research*, 295(2), 295-336.

Chin, W.W. (2010). "How to write up and report PLS analyses." *In Handbook of partial least squares*, 655-690.

Choi, B., Ahn, S. and Lee, S. (2017). "Construction workers' group norms and personal standards regarding safety behaviour: Social identity theory perspective." *Journal of Management in Engineering*, 33(4), 04017001.

Choudhry, R.M., and Zahoor, H. (2016). "Strengths and weaknesses of safety practices to improve safety performance in construction projects in Pakistan." *Journal of Professional Issues in Engineering Education and Practice*, 142(4), 04016011.

Choudhry, R.M., Fang, D.P., and Ahmed, S.M. (2008). "Safety management in construction: Best practices in Hong Kong." *Journal of Professional Issues in Engineering Education and Practice*, 134(1), 20-32.

Choudhry, R.M., Fang, D., and Lingard, H. (2009). "Measuring safety climate of a construction company." *Journal of Construction Engineering and Management*, 135(9), 890-899.

Choudhry, R.M., Fang, D., and Mohamed, S. (2007). "Developing a model of construction safety culture." *Journal of Management in Engineering*, 23(4), 207-212.

Choudhry, R.M., Fang, D., and Mohamed, S. (2007). "The nature of safety culture: A survey of the state-of-the-art." *Safety Science*, 45, 993-1012.

Chuks, O.K., and Uchenna, O.P. (2013). "Appraising the influence of cultural determinants of construction workers safety perception and behaviour in Nigeria." *International Journal of Engineering and Medical Science Research*, 1(1), 11-24.

Cigularov, K.P., Adams, S., Gittleman, J.L., Haile, E., and Chen, P.Y. (2013a). "Measurement equivalence and mean comparisons of a safety climate measure across construction trades." *Accident Analysis and Prevention*, 51, 68-77.

Cigularov, K.P., Chen, P.Y., Rosecrance, J. (2010). "The effects of error management climate and safety communication on safety: A multi-level study." *Accident Analysis and Prevention*, 42(5), 1498-1506.

Cigularov, K.P., Lancaster, P.G., Chen, P.Y., Gittleman, J., and Haile, E. (2013b). "Measurement equivalence of a safety climate measure among Hispanic and white Non-Hispanic construction workers." *Safety Science*, 54, 58-68.

CIRC (Construction Industry Review Committee). (2001). "Construct for Excellence-Report of the Construction Industry Review Committee." Hong Kong Special Administrative Region Government, Hong Kong SAR, 207.

Clarke, S. (2000). "Safety culture: Under-specified and overrated?" *International Journal of Management Reviews*, 2, 65–90.

Clarke, S. (2013). "Safety leadership: A meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours." *Journal of Occupational and Organizational Psychology*, 86(1), 22-49.

Clarke, S. and Ward, K. (2006). "The role of leader influence tactics and safety climate in engaging employees' safety participation." *Risk Analysis*, 26(5), 1175-1185.

Cohen, J. (1988). "Statistical power analysis for the behavioral sciences." Routledge.

Colicchia, C., and Strozzi, F. (2012). "Supply chain risk management: A new methodology for a systematic literature review." *Supply Chain Management: An International Journal*, 17(4), 403-418.

Colley, S.K., Lincolne, J., and Neal, A. (2013). "An examination of the relationship amongst profiles of perceived organizational values, safety climate and safety outcomes." *Safety Science*, 51(1), 69-76.

Cooper, M.D. and Phillips, R.A. (2004). "Exploratory analysis of the safety climate and safety behavior relationship." *Journal of Safety Research*, 35(5), 497-512.

Cooper, M. D. (2000). "Towards a model of safety culture." *Safety Science*, 36(2), 111–136.

Cooper, M.D. (2016). "Navigating the Safe Culture Construct: A Review of the Evidence", Be-Safe Management Solutions Evidence Incorporation (BSMS).

Cox, S.J., and Cheyne, A.J.T. (2000). "Assessing safety culture in offshore environments." Safety Science, 34(1-3), 111-129.

Cox, S., Tomás, J.M., Cheyne, A., and Oliver, A. (1998). "Safety culture: the prediction of commitment to safety in the manufacturing industry." *British Journal of Management*, 9(s1), 3-11.

Creswell, J.W. (2009). "Research design: Qualitative, quantitative, and mixed methods approaches." Sage, Publications Los Angeles: University of Nebraska–Lincoln, USA.

Creswell, J.W., and Plano Clark, V.L. (2011). "Designing and conducting mixed methods research." Sage Publications, Thousand Oaks, London.

Dainty, A. (2008). "Methodological Pluralism in Construction Management," Advanced Research Methods in Built Environment, United Kingdom: Wiley-Blackwell, 1-12.

Davies, F., Spencer, R. and Dooley, K. (2001). "Summary guide to safety climate tools." Norwich, UK: HSE Books.

Dawson, S. (1992). "Analyzing organizations." Springer Publications. University of London, London.

De Silva, N., Rathnayake, U., and Kulasekera, K.M.U.B. (2018). "Under-reporting of construction accidents in Sri Lanka." *Journal of Engineering, Design and Technology*, 16(6), 850-868.

De Winter, J.C.F., Dodou, D., and Wieringa, P. A. (2009). "Exploratory factor analysis with small sample sizes." *Multivariate Behavioral Research*, 44, 147-181.

Dedobbeleer, N. and Béland, F. (1991), "A safety climate measure for construction sites." *Journal of Safety Research*, 22(2), 97-103.

DeJoy, D.M. (2005). "Behavior change versus culture change: Divergent approaches to managing workplace safety." *Safety Science*, 43, 105–129.

Dester, W.S. and Blockley, D.I. (1995). "Safety-behaviour and culture in construction." *Engineering Construction and Architectural Management*, 2(1), 17-26.

Dingsdag, D. P., Biggs, H. C., and Sheahan, V. L. (2008). "Understanding and defining OH&S competency for construction site positions: Worker perceptions." *Safety Science*, 46(4), 619-633.

Dixit, S., Mandal, S.N., Thanikal, J.V., and Saurabh, K. (2018). "Critical analysis of factors affecting the on-site productivity in Indian construction industry" *Proceedings of the Creative Construction Conference 2018*, Ljubljana, Slovenia, 38-45.

Dov, Z. (2008). "Safety climate and beyond: A multi-level multi-climate framework." *Safety Science*, 46(3), 376-387.

Durdyev, S., Ismail, S., and Kandymov, N. (2018). "Structural equation model of the factors affecting construction labour productivity." *Journal of Construction Engineering and Management*, 144(4), 04018007.

Easterby-Smith, M., Thorpe, R., and Jackson, P., (2012). "Management Research." Sage Publications, London.

Edelson, J., Neitzel, R., Meischke, H., Daniell, W., Sheppard, L., Stover, B., and Seixas, N. (2009). "Predictors of hearing protection use in construction workers." *Annals of Occupational Hygiene*, 53(6), 605-615.

El-Mashaleh, M.S., Rababeh, S.M., and Hyari, K.H. (2010). "Utilizing data envelopment analysis to benchmark safety performance of construction contractors." *International Journal of Project Management*, 28(1), 61-67.

Escorcia, Y.C., Ochoa, G.V., and Ruiz, Y.P. (2018). "Management of Occupational Safety and Health Using VC-OHSAS 18001 v 1.0." *Contemporary Engineering Sciences*, 11(57), 2813-2820.

EU-OSHA (European Agency for Safety and Health at Work), (2011). "Occupational safety and health culture assessment - A review of main approaches and selected tools." Working Environment Information Working Paper. Publications Office of the European Union, Luxembourg.

Fang, D. and Wu, H. (2013). "Development of a safety culture interaction (SCI) model for construction projects." *Safety Science*, 57, 138-149.

Fang, D.P., Huang, X.Y., and Hinze, J. (2004). "Benchmarking studies on construction safety management in China." *Journal of Construction Engineering and Management*, 130(3), 424-432.

Fang, D., Chen, Y. and Wong, L. (2006). "Safety climate in construction industry: A case study in Hong Kong." *Journal of Construction Engineering and Management*, 132(6), 573-584.

Fang, D., Wu, C., and Wu, H. (2015). "Impact of the supervisor on worker safety behaviour in construction projects." *Journal of Management in Engineering*, 31(6), 04015001.

Fargnoli, M., De Minicis, M., and Di Gravio, G. (2011). "Knowledge management integration in occupational health and safety systems in the construction industry." *International Journal of Product Development*, 14(1-4), 165-185.

Farooqui, R.U., Ahmed, S.M., and Lodi, S.H. (2008). "Assessment of Pakistani construction industry current performance and the way forward." *Journal for the Advancement of Performance Information and Value*, 1(1), 51-72.

Fellows, R.R. and Liu, A. (2008). "Research Methods for Construction" John Wiley & Sons, London.

Feng, Y. (2013). "Effect of safety investments on safety performance of building projects." *Safety Science*, 59, 28-45.

Feng, Y., Teo, E.A.L., Ling, F.Y.Y., and Low, S.P. (2014). "Exploring the interactive effects of safety investments, safety culture and project hazard on safety performance: An empirical analysis." *International Journal of Project Management*, 32(6), 932-943.

Fernandes, V. (2012). "(Re) discovering the PLS approach in management science." *Management*, 15(1), 101-123.

Fernández-Muñiz, B., Montes-Peón, J.M., and Vázquez-Ordás, C.J. (2012). "Safety climate in OHSAS 18001-certified organizations: Antecedents and consequences of safety behaviour." *Accident Analysis & Prevention*, 45, 745-758.

Fernández-Muñiz, B., Montes-Peón, J. M., and Vázquez-Ordás, C.J. (2012). "Occupational risk management under the OHSAS 18001 standard: Analysis of perceptions and attitudes of certified firms." *Journal of Cleaner Production*, 24, 36-47.

Field, A. (2013). "Discovering statistics using IBM SPSS statistics" Sage Publications.

Firoozi, N.H., and Hatami, A. (2017). "Health and safety culture as a competitive advantage for knowledge-based organizations: An HSEC model perspective." *Knowledge and Process Management*, 24(3), 188-195.

Fleming, M., and Wentzell, N. (2008). "Patient safety culture improvement tool: Development and guidelines for use." *Healthc Q*, 11(3), 10-5.

Fleming, M., Harvey, K., and Cregan, B. (2018). "Safety culture research and practice: A review of 30 years of research collaboration." *Journal of Applied Biobehavioral Research*, 23(4), e12155.

Flin, R. (2007). "Measuring safety culture in healthcare: A case for accurate diagnosis." *Safety Science*, 45(6), 653-667.

Flin, R., Burns, C., Mearns, K., Yule, S., and Robertson, E.M. (2006). "Measuring safety climate in health care." *BMJ Quality & Safety*, 15(2), 109-115.

Flin, R., Mearns, K., O'Connor, P. and Bryden, R. (2000). "Measuring safety climate: Identifying the common features." *Safety Science*, 34(1), 177-192.

Frazier, C.B., Ludwig, T.D., Whitaker, B., and Roberts, D.S. (2013). "A hierarchical factor analysis of a safety culture survey." *Journal of Safety Research*, 45, 15-28.

Fung, I.W., Tam, C.M., Tung, K.C., and Man, A.S. (2005). "Safety cultural divergences among management, supervisory and worker groups in Hong Kong construction industry." *International Journal of Project Management*, 23(7), 504-512.

Gabryelewicz, I., Sadłowska-Wrzesińska, J., and Kowal, E. (2015). "Evaluation of safety climate level in a production facility." *Procedia Manufacturing*, 3, 5822-5829.

Gadd, S. and Collins, A.M. (2002), "Safety culture: A review of the literature", Health and Safety Laboratory, Sheffield, U.K.

Gao, R., Chan, A. P., Utama, W. P., and Zahoor, H. (2016). "Workers' perceptions of safety climate in international construction projects: Effects of nationality, religious belief, and employment mode." *Journal of Construction Engineering and Management*, 143(4), 04016117.

Gao, R., Chan, A., Utama, W., and Zahoor, H. (2016). "Multilevel safety climate and safety performance in the construction industry: Development and validation of a top-down mechanism." *International Journal of Environmental Research and Public Health*, 13(11), 1100.

Gaureanu, A., Weinschrott, H., Draghici, A., and Jitarel, A. (2016). "Knowledge management impact on the occupational safety and health culture in enterprise." *Proceedings of the MakeLearn and TIIM Joint International Conference, Timisoara, Romania*, 539-547.

Gefen, D., Straub, D., and Boudreau, M.C. (2000). "Structural equation modeling and regression: Guidelines for research practice." *Communications of The Association For Information Systems*, 4(1), 7.

Ghahramani, A. (2016). "Factors that influence the maintenance and improvement of OHSAS 18001 in adopting companies: A qualitative study." *Journal of Cleaner Production*, 137, 283-290.

Ghahramani, A., and Salminen, S. (2019). "Evaluating effectiveness of OHSAS 18001 on safety performance in manufacturing companies in Iran." *Safety Science*, 112, 206-212.

Gherardi, S., and Nicolini, D. (2002). "Learning the trade: A culture of safety in practice." *Organization*, 9(2), 191-223.

Gherardi, S., Nicolini, D., and Odella, F. (1998). "What do you mean by safety? Conflicting perspectives on accident causation and safety management in a construction firm." *Journal of Contingencies and Crisis Management*, 6(4), 202-213.

Gilkey, D.P., del Puerto, C.L., and Keefe, T. (2011). "Comparative analysis of safety culture perceptions among homesafe managers and workers in residential construction." *Journal of Construction Engineering and Management*, 138(9), 1044-1052.

Gilkey, D., Lopez del Puerto, C., Chen, P., and Rosecrance, J. (2013). "Comparative analysis of safety culture and risk perceptions among Latino and non-Latino workers in the construction industry." *Journal of Safety, Health and Environmental Research*, 9, 94–104.

Gillen, M., Baltz, D., Gassel, M., Kirsch, L., and Vaccaro, D. (2002). "Perceived safety climate, job demands, and co-worker support among union and non-union injured construction workers." *Journal of Safety Research*, 33(1), 33-51.

Gittleman, J.L., Gardner, P.C., and Haile, E. (2010). "Case study city centre and cosmopolitan construction projects, Las Vegas, Nevada: Lessons learned from the use of multiple sources and mixed methods in a safety needs assessment." *Journal of Safety Research*, 41, 263–281.

Givehchi, S., Hemmativaghef, E., and Hoveidi, H. (2017). "Association between safety leading indicators and safety climate levels." *Journal of Safety Research*, 62, 23-32.

Glendon, A.I. and Litherland, D.K. (2001). "Safety climate factors, group differences and safety behaviour in road construction." *Safety Science*, 39(3), 157-188.

Glendon, A.I., and Stanton, N.A. (2000). "Perspectives on safety culture." *Safety Science*, 34(1-3), 193-214.

Goel, A.K., Rana Sharma, G. and Rastogi, R. (2010). "Knowledge management implementation in NTPC: An Indian PSU." *Management Decision*, 48(3), 383-395.

Gressgård, L.J. (2014). "Knowledge management and safety compliance in a high-risk distributed organizational system." *Safety and Health at Work*, 5(2), 53-59.

Griffin, M.A. and Neal, A. (2000). "Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation." *Journal of Occupational Health Psychology*, 5(3), 347.

Grote, G. (2008). "Diagnosis of safety culture: A replication and extension towards assessing 'safe' organizational change processes." *Safety Science*, 46(3), 450-460.

Grote, G. and Künzler, C. (2000). "Diagnosis of safety culture in safety management audits." *Safety Science*, 34(1), 131-150.

Grover, R., and Froese, T.M. (2016). "Knowledge management in construction using a SocioBIM platform: A case study of AYO smart home project." *Procedia Engineering*, 145, 1283-1290.

Guldenmund, F.W. (2010). "Understanding and exploring safety culture." Ph.D. thesis, Delft University of Technology, Delft, Netherlands.

Guldenmund, F.W. (2000). "The nature of safety culture: a review of theory and research." *Safety Science*, 34(1-3), 215–257.

Gunduz, M., Birgonul, M.T., and Ozdemir, M. (2016). "Fuzzy structural equation model to assess construction site safety performance." *Journal of Construction Engineering and Management*, 143(4), 04016112.

Gürcanli, G. E., and Müngen, U. (2013). "Analysis of construction accidents in Turkey and responsible parties." *Industrial Health*, 51(6), 581-595.

Hair, J.F. Black. W.C., Babin, B.J., and Anderson R.E. (2010). "Multivariate data analysis, a global perspective." Pearson Prentice Hall, London.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., and Tatham, R.L. (2007). "Multivariate data analysis." Pearson Prentice Hall, London.

Hair, J.F., Celsi, M., Money, A., Samouel, P., and Page, M. (2016). "Essentials of business research methods." Routledge, New York, USA, 237–238.

Hair, J.F., Sarstedt, M., Ringle, C.M., and Mena, J.A. (2012). "An assessment of the use of partial least squares structural equation modeling in marketing research." *Journal of the Academy of Marketing Science*, 40(3), 414-433.

Hair, J.F, Sarstedt, M., Pieper, T., and Ringle, C.M., (2012). "The use of partial least squares structural equation modelling in strategic management research: A review of past practices and recommendations for future applications." *Long Range Planning*, 45, 320-340.

Hale, A.R. (2000). "Culture's confusions." *Safety Science*, 34, 1–14.

Hale, A.R., Guldenmund, F.W., van Loenhout, P.L.C.H., and Oh, J.I.H. (2010). "Evaluating safety management and culture interventions to improve safety: Effective intervention strategies." *Safety Science*, 48, 1026–1035.

Hallowell, M.R. (2011). "Safety-knowledge management in American construction organizations." *Journal of Management in Engineering*, 28(2), 203-211.

Han, S., Saba, F., Lee, S., Mohamed, Y., Peña-Mora, F. (2014). "Toward an understanding of the impact of production pressure on safety performance in construction operations." *Accident Analysis and Prevention*, 68, 106-116.

Hansen, E. (2006). "Successful Qualitative Health Research: A Practical Introduction." Allen & Unwin, Sydney, Australia.

Hartley, R., and Cheyne, A. (2012). "Safety culture in the construction industry." *Contemporary Ergonomics and Human Factors 2012: Proceedings of the international conference on Ergonomics and Human Factors*, pp.295.

Haslam, C., O'Hara, J., Kazi, A., Twumasi, R., and Haslam, R. (2016). "Proactive occupational safety and health management: Promoting good health and good business." *Safety Science*, 81, 99-108.

Haukelid, K. (2008). "Theories of (safety) culture revisited-An anthropological approach." *Safety Science*, 46(3), 413-426.

Healy, N., and Sugden, C. (2012). "Safety culture on the Olympic Park." Health and Safety Executive, Research Report, 942.

Henroid Jr, D., and Sneed, J. (2004). "Readiness to implement hazard analysis and critical control point (HACCP) systems in Iowa schools." *Journal of the American Dietetic Association*, 104(2), 180-185.

Henseler, J., and Sarstedt, M. (2013). "Goodness-of-fit indices for partial least squares path modeling." *Computational Statistics*, 28(2), 565-580.

Hensler, D. R. (2009). "The globalization of class actions: An overview." *The ANNALS of the American Academy of Political and Social Science*, 622(1), 7-29.

Hinze, J.W. (1997). "Construction safety." Prentice-Hall Inc., Upper Saddle River, New Jersey, USA.

Ho, J.K.L. and Zeta, K.C. (2004). "Cultural factors and their significance to the Hong Kong construction industry." *Safety Science*, 39, 157-188.

Hoffmeister, K., Gibbons, A. M., Johnson, S. K., Cigularov, K. P., Chen, P. Y., and Rosecrance, J. C., (2014). "The differential effects of transformational leadership facets on employee safety." *Safety Science*, 62, 68-78.

Hofstede, G. (1991). "Cultures and Organizations: Software of the Mind." McGraw-Hill Publications, London, UK.

HSE (Health and Safety Executive) (2005). "A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit." Research Report 367. London, UK.

Hohnen, P., and Hasle, P. (2011). "Making work environment auditable–A 'critical case'study of certified occupational health and safety management systems in Denmark." *Safety Science*, 49(7), 1022-1029.

Hon, C.K., Chan, A.P., and Yam, M.C. (2012). "Determining safety climate factors in the repair, maintenance, minor alteration, and addition sector of Hong Kong." *Journal of Construction Engineering and Management*, 139(5), 519-528.

Hon, C.K., Chan, A.P., and Yam, M.C. (2014). "Relationships between safety climate and safety performance of building repair, maintenance, minor alteration, and addition (RMAA) works." *Safety Science*, 65, 10-19.

Hon, C.K., and Chan, A.P. (2013). "Safety management in repair, maintenance, minor alteration, and addition works: knowledge management perspective." *Journal of Management in Engineering*, 30(6), 04014026.

Høyland, S.A., Skotnes, R.Ø., and Holte, K.A. (2018). "An empirical exploration of the presence of HRO safety principles across the health care sector and construction industry in Norway." *Safety Science*, 107, 161-172.

Hrenov, G., Reinhold, K., and Tint, P. (2017). "Working environment specialist's role in improvement of safety level in Estonian enterprises." *Proceedings of the International Scientific Conference*, Latvia University of Agriculture.

HSE (Health and Safety Executive), (1988). "Blackspot construction: A study of five years of fatal accidents in the building and civil engineering industries." London.

Huang, C.C., Wang, Y.M., Wu, T.W., and Wang, P.A. (2013). "An empirical analysis of the antecedents and performance consequences of using the moodle platform." *International Journal of Information and Education Technology*, 3(2), 217.

Hussain, S., FangWei, Z., and Ali, Z. (2019). "Examining influence of construction projects' quality factors on client satisfaction using partial least squares structural equation modeling." *Journal of Construction Engineering and Management*, 145(5), 05019006.

IAEA. (1986). "Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident (International Safety Advisory Group, Safety-Series 75 - INSAG-1)." International Atomic Energy Agency, Vienna, Austria.

IAEA. (1991). "Safety Culture (International Safety Advisory Group, Safety-Series 75 - INSAG-1)." International Atomic Energy Agency, Vienna, Austria.

ILO-OSH. (2001). "Guidelines on occupational safety and health management systems." ILO-OSH, International Labour Office, Geneva, Switzerland.

IS-2014 (Infrastructure Statistics-2014). (2014). *Ministry of Statistics and Programme Implementation*, Government of India, New Delhi.

Ismail, Z., Doostdar, S., and Harun, Z. (2012). "Factors influencing the implementation of a safety management system for construction sites." *Safety Science*, 50(3), 418-423.

Järvis, M., Virovere, A. and Tint, P. (2014). "Knowledge management - A neglected dimension in discourse on safety management and safety culture-evidence from Estonia." *Safety of Technogenic Environment*. 5-17.

Järvis, M., Virovere, A., and Tint, P. (2016). "Formal safety versus real safety: Quantitative and qualitative approaches to safety culture–evidence from Estonia." *Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences*, 70(5), 269-277.

Jaselskis, E.J., Strong, K.C., Aveiga, F., Canales, A.R., and Jahren, C. (2008). "Successful multi-national workforce integration program to improve construction site performance." *Safety Science*, 46(4), 603-618.

Jesson, J., Matheson, L., and Lacey, F.M., (2011). "Doing your literature review: Traditional and systematic techniques." SAGE Publications, Thousand Oaks, CA, United States.

Jia, X., Dai, T., and Guo, X. (2014). "Comprehensive exploration of urban health by bibliometric analysis: 35 years and 11,299 articles." *Scientometrics*, 99(3), 881–894.

Jiang, L., and Probst, T.M. (2016). "A multilevel examination of affective job insecurity climate on safety outcomes." *Journal of Occupational Health Psychology*, 21(3), 366.

Jick, T.D. (1979). "Mixing qualitative and quantitative methods: Triangulation in action." *Administrative Science Quarterly Report*, 24(4), 602-611.

Jimoh R.A. (2012). "Strategies for sustainable housing co-operatives in South Africa." PhD Thesis, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Johnson, G. and Scholes, K. (1999). "Exploring Corporate Strategy." Prentice-Hall, U.K.

Johnson, R.B., Onwuegbuzie, A.J., and Turner, L.A. (2007). "Toward a definition of mixed methods research." *Journal of Mixed Methods Research*, 1(2), 112-133.

Jones, C. (2014). "Assessing safety culture and safety performance in a high hazard industry." PhD Thesis, University of Nottingham, U.K.

Jorgensen, E., Sokas, R.K., Nickels, L., Gao, W., Gittleman, J.L., (2007). "An English/Spanish safety climate scale for construction workers." *American Journal of Industrial Medicine*, 50(6), 438-442.

Kapp, E.A. (2012). "The influence of supervisor leadership practices and perceived group safety climate on employee safety performance." *Safety Science*, 50(4), 1119-1124.

Kartam, N.A., Flood, I. and Koushki, P. (2000). "Construction safety in Kuwait: Issues, procedures, problems, and recommendations." *Safety Science*, 36(3), 163-184.

Kennedy, R. and Kirwan, B. (1998). "Development of a hazard and operability-based method for identifying safety management vulnerabilities in high risk systems." *Safety Science*, 30(3), 249-274.

Khosravi, Y., Asilian-Mahabadi, H., Hajizadeh, E., Hassanzadeh-Rangi, N., Bastani, H., and Behzadan, A.H. (2014). "Factors influencing unsafe behaviors and accidents on construction sites: A review." *International Journal of Occupational Safety and Ergonomics*, 20(1), 111-125.

Kim, N.K., Rahim, N.F.A., Iranmanesh, M., and Foroughi, B. (2019). "The role of the safety climate in the successful implementation of safety management systems." *Safety Science*, 118, 48-56.

Kines, P., Andersen, L.P., Spangenberg, S., Mikkelsen, K.L., Dyreborg, J., and Zohar, D. (2010). "Improving construction site safety through leader-based verbal safety communication." *Journal of Safety Research*, 41(5), 399-406.

Kines, P., Lappalainen, J., Mikkelsen, K.L., Olsen, E., Pousette, A., Tharaldsen, J., and Törner, M. (2011). "Nordic Safety Climate Questionnaire (NOSACQ-50): A new tool for diagnosing occupational safety climate." *International Journal of Industrial Ergonomics*, 41(6), 634-646.

Kirk, S., Parker, D., Claridge, T., Esmail, A., and Marshall, M. (2007). "Patient safety culture in primary care: Developing a theoretical framework for practical use." *BMJ Quality & Safety*, 16(4), 313-320.

Koivupalo, M., Sulasalmi, M., Rodrigo, P., and Väyrynen, S. (2015). "Health and safety management in a changing organisation: Case study global steel company." *Safety Science*, 74, 128-139.

Kothari, C.R. (2004). "Research Methodology: Methods and techniques." New Age International, India.

Kulkarni, G.K. (2007). "Construction industry: More needs to be done." *Indian Journal of Occupational and Environmental Medicine*, 11(1), 1.

Langford, D., Rowlinson, S. and Sawacha, E. (2000). “Safety behaviour and safety management: its influence on the attitudes of workers in the UK construction industry.” *Engineering, Construction and Architectural Management*, 7(2), 133-140.

Larsson, S., Pousette, A., and Törner, M. (2008). “Psychological climate and safety in the construction industry-mediated influence on safety behaviour.” *Safety Science*, 46(3), 405-412.

Latief, Y., Machfudiyanto, R.A., Arifuddin, R., Setiawan, R.M.F., and Yogiswara, Y. (2017). “Study of evaluation OSH management system policy based on safety culture dimensions in construction project.” *International Conference on Energy Sciences: Bandung - Indonesia, Journal of Physics: Conference Series*, 877-884.

Leidner, D., Alavi, M., and Kayworth, T. (2006). “The role of culture in knowledge management: A case study of two global firms.” *International Journal of e-Collaboration*, 2(1), 17-40.

Li, H., Lu, M., Hsu, S.C., Gray, M., and Huang, T. (2015). “Proactive behaviour-based safety management for construction safety improvement.” *Safety Science*, 75, 107-117.

Li, J., and Tong, R. (2018). “A structured and hierarchical safe climate model and its application to safe communities.” *Safety and Reliability*, 38(3), 137-170.

Li, J., and Hale, A. (2016). “Output distributions and topic maps of safety related journals.” *Safety Science*, 82, 236–244.

Li, Q., Ji, C., Yuan, J., and Han, R. (2017). “Developing dimensions and key indicators for the safety climate within China’s construction teams: A questionnaire survey on construction sites in Nanjing.” *Safety Science*, 93, 266-276.

Liao, P.C., Lei, G., Fang, D., and Liu, W. (2014). “The relationship between communication and construction safety climate in China.” *KSCE Journal of Civil Engineering*, 18(4), 887-897.

Liao, P.C., Lei, G., Xue, J., and Fang, D. (2013). “Influence of person-organizational fit on construction safety climate.” *Journal of Management in Engineering*, 31(4), 04014049.

Liebowitz, J., and Megbolugbe, I. (2003). “A set of frameworks to aid the project manager in conceptualizing and implementing knowledge management initiatives.” *International Journal of Project Management*, 21(3), 189-198.

Lin, S.H., Tang, W.J., Miao, J.Y., Wang, Z.M., and Wang, P.X. (2008). “Safety climate measurement at workplace in China: A validity and reliability assessment.” *Safety Science*, 46(7), 1037-1046.

Lingard, H.C., Cooke, T., and Blismas, N. (2009). “Group-level safety climate in the Australian construction industry: Within-group homogeneity and between-group differences in road construction and maintenance.” *Construction Management and Economics*, 27(4), 419-432.

Lingard, H.C., Cooke, T., and Blismas, N. (2010). "Safety climate in conditions of construction subcontracting: A multi-level analysis." *Construction Management and Economics*, 28(8), 813-825.

Lingard, H., Zhang, R., Harley, J., Blismas, N., and Wakefield, R. (2014). "Health and safety culture.": Centre for Construction Work Health and Safety, Melbourne, Australia.

Lingard, H., and Rowlinson, S. (1997). "Behavior-based safety management in Hong Kong's construction industry." *Journal of Safety Research*, 28(4), 243-256.

Lingard, H., and Yesilyurt, Z. (2003). "The effect of attitudes on the occupational safety actions of Australian construction workers: The results of a field study." *Journal of Construction Research*, 4(01), 59-69.

Lingard, H., Cooke, T., and Blismas, N. (2012). "Do perceptions of supervisors' safety responses mediate the relationship between perceptions of the organizational safety climate and incident rates in the construction supply chain?." *Journal of Construction Engineering and Management*, 138(2), 234-241.

Loosemore, M., Sunindijo, R.Y., Lestari, F., Kusminanti, Y., and Widanarko, B. (2019). "Comparing the safety climate of the Indonesian and Australian construction industries: Cultural and institutional relativity in safety research." *Engineering, Construction and Architectural Management*. 26(10), 2206-2222.

Lopez del Puerto, C., Clevenger, C.M., Boremann, K., and Gilkey, D.P. (2013). "Exploratory study to identify perceptions of safety and risk among residential Latino construction workers as distinct from commercial and heavy civil construction workers." *Journal of Construction Engineering and Management*, 140(2), 04013048.

Machfudiyanto, R.A., Latief, Y., Arifuddin, R., and Yogiswara, Y. (2017). "Identification of safety culture dimensions based on the implementation of OSH management system in Construction Company." *Procedia Engineering*, 171, 405-412.

Marhani, M.A., Adnan, H., and Ismail, F. (2013). "OHSAS 18001: A pilot study of towards sustainable construction in Malaysia." *Procedia-Social and Behavioral Sciences*, 85, 51-60.

Martin, H., and Lewis, T.M. (2013). "Pinpointing safety leadership factors for safe construction sites in Trinidad and Tobago." *Journal of Construction Engineering and Management*, 140(2), 04013046.

Masood, R., Choudhry, R.M., Riaz, Z., Azhar, S., and Hinze, J. (2012). "Role of managers in establishment of construction safety culture." *CIB W099 International Conference 'Modeling and Building Health and Safety,* Singapore, 651-659.

McDonald, M.A., Lipscomb, H.J., Bondy, J. and Glazner, J. (2009), "Safety is everyone's job: The key to safety on a large university construction site." *Journal of Safety Research*, 40(1), 53-61.

McDonald, N., Corrigan, S., Daly, C. and Cromie, S. (2000). "Safety management systems and safety culture in aircraft maintenance organizations." *Safety Science*, 34(1), 151-176.

Mearns, K., Whitaker, S.M. and Flin, R. (2003), "Safety climate, safety management practice and safety performance in offshore environments." *Safety Science*, 41(8), 641-680.

Meliá, J.L., Mearns, K., Silva, S.A., and Lima, M.L. (2008). "Safety climate responses and the perceived risk of accidents in the construction industry." *Safety Science*, 46(6), 949-958.

Merill, P. (2008). "Innovation generation: Creating an innovation process and an innovative culture." ASQ Quality press.

Misnan, M.S., and Mohammed, A.H. (2007). "Development of safety culture in the construction industry: A conceptual framework." *Proceedings 23rd Annual ARCOM Conference*, 3-5.

Misnan, M.S., Mohammed, A.H., Mahmood, W., Yusoff, W., Mahmud, S.H., and Abdullah, M.N. (2008). "Development of safety culture in the construction industry: The leadership and training roles." *ICBEDC 2008 – 2nd International Conference on Built Environment in Developing Countries*, Penang, Malaysia.

Mohamed, S. (2002). "Safety climate in construction site environments." *Journal of Construction Engineering and Management*, 128(5), 375-384.

Mohamed, S. (2003). "Scorecard approach to benchmarking organizational safety culture in construction." *Journal of Construction Engineering and Management*, 129(1), 80–88.

Mohamed, S., Ali, T.H., and Tam, W.Y.V. (2009). "National culture and safe work behaviour of construction workers in Pakistan." *Safety Science*, 47(1), 29-35.

Mohammadfam, I., Kamalinia, M., Momeni, M., Golmohammadi, R., Hamidi, Y., and Soltanian, A. (2017). "Evaluation of the quality of occupational health and safety management systems based on key performance indicators in certified organizations." *Safety and Health at Work*, 8(2), 156-161.

Molenaar, K.R., Park, J.I., and Washington, S. (2009). "Framework for measuring corporate safety culture and its impact on construction safety performance." *Journal of Construction Engineering and Management*, 135(6), 488-496.

Molenaar, K., Brown, H., Caile, S., and Smith, R. (2002). "Corporate culture." *Professional Safety*, 47(7), 18-27.

Molina-Azorin, J.F. (2012). "Mixed methods research in strategic management: Impact and applications." *Organizational Research Methods*, 15(1), 33-56.

Mullen, J., Kelloway, E.K., and Teed, M. (2017). "Employer safety obligations, transformational leadership and their interactive effects on employee safety performance." *Safety Science*, 91, 405-412.

Mundfrom, D., Shaw, D., and Ke, T. (2005). "Minimum sample size recommendations for conducting factor analyses." *International Journal of Testing*, 5(2), 159-168.

Nandakumar, M.K. (2008). "Strategy formulation and implementation in manufacturing organizations - the impact on Performance." Unpublished Ph.D. thesis, Middlesex University Business School, London, UK.

Neal, A., Griffin, M.A. and Hart, P.M. (2000). "The impact of organizational climate on safety climate and individual behavior." *Safety Science*, 34(1), 99-109.

Neuman, W.L (1997). "Social research methods: Qualitative and quantitative approaches." Allyn & Bacon, USA,

Ng, S.T., Cheng, K. P., and Skitmore, R. M. (2005). "A framework for evaluating the safety performance of construction contractors." *Building and Environment*, 40(10), 1347-1355.

Ngai, E.W.T., Moon, K.K., Riggins, F.J., Candace, Y.Y. (2008). "RFID research: An academic literature review (1995–2005) and future research directions." *International Journal of Production Economics*, 112(2), 510-520.

Nielsen, K.J. (2014). "Improving safety culture through the health and safety organization: A case study." *Journal of Safety Research*, 48, 7-17.

Niskanen, T. (1994). "Safety climate in the road administration." *Safety Science*, 17(4), 237-255.

Niu, M., Leicht, R.M., Rowlinson, S. (2016). "Overview and analysis of safety climate studies in the construction industry." *Construction Research Congress 2016*, 2926-2935.

NPSA. (2004). "Seven steps to patient safety: The full reference guide." National Patient Safety Agency, London.

Nuñez, I. and Villanueva, M. (2011). "Safety Capital: The management of organizational knowledge on occupational health and safety." *Journal of Workplace Learning*, 23(1), 56-71.

Nunnally, J.C. and Bernstein, I.H. (1994). "Psychometric Theory." McGraw-Hill Publishers, New York, USA.

OHSAS, B. S. (2007). "18001: 2007. Occupational health and safety management systems." London.

Oswald, D. (2017). "An ethnographic investigation into a series of incidents on a large construction project." *EPiC Series in Education Science*, 1, 62-69.

Oyewobi, L.O. (2014). "Modeling performance differentials in large construction organizations in South Africa." PhD Thesis, University of Cape Town, South Africa.

Paas, Õ., Reinhold, K., and Tint, P. (2015). "OHSAS 18001 contribution to real and formal safety elements in safety management system in manufacturing." *Agronomy Research*, 13(5), 1260-1274.

Patel, D.A., and Jha, K.N. (2014). "Neural network approach for safety climate prediction." *Journal of Management in Engineering*, 31(6), 05014027.

Patel, D.A., and Jha, K.N. (2014). "Neural network model for the prediction of safe work behaviour in construction projects." *Journal of Construction Engineering and Management*, 141(1), 04014066.

Patel, D.A., and Jha, K.N. (2016). "Evaluation of construction projects based on the safe work behaviour of co-employees through a neural network model." *Safety Science*, 89, 240-248.

Patel, D.A., and Jha, K.N. (2016). "Structural equation modelling for relationship-based determinants of safety performance in construction projects." *Journal of Management in Engineering*, 32(6), 05016017.

Patton, M. (1990). "Qualitative evaluation and research methods." Sage Publications, Newbury park, California, USA.

Perneger, T.V. (2006). "A research agenda for patient safety." *International Journal for Quality in Health Care*, 18(1), 1–3.

Pheng, L.S., and Pong, C.Y. (2003). "Integrating ISO 9001 and OHSAS 18001 for construction." *Journal of Construction Engineering and Management*, 129(3), 338-347.

Pidgeon, N.F. (1991). "Safety culture and risk management in organizations." *Journal of Cross-Cultural Psychology*, 22(1), 129-140.

Podgórski, D. (2010). "The use of tacit knowledge in occupational safety and health management systems." *International Journal of Occupational Safety and Ergonomics*, 16(3), 283-310.

Pousette, A., Larsson, S., and Törner, M. (2008). "Safety climate cross-validation, strength and prediction of safety behaviour." *Safety Science*, 46(3), 398-404.

Preacher, K.J., and MacCallum, R.C. (2002). "Exploratory factor analysis in behavior genetics research: Factor recovery with small sample sizes." *Behavior Genetics*, 32(2), 153-161.

Probst, T.M., Brubaker, T.L., Barsotti, A. (2008). "Organizational injury rate underreporting: the moderating effect of organizational safety climate." *Journal of Applied Psychology*, 93(5), 1147-1154.

Proverbs, D. and Gameson, R. (2008). "Case study research." Advanced Research Methods in Built Environment, Wiley-Blackwell, United Kingdom, 99-110.

Pungvongsanuraks, P., and Chinda, T. (2010). "Investigation of safety perceptions of management and workers in Thai construction industry." *Suranaree Journal of Science & Technology*, 17(2), 177-191.

Qu, S. Q., and Dumay, J. (2011). "The qualitative research interview." *Qualitative Research in Accounting & Management*, 8(3), 238-264.

Raheem, A.A., Issa, R.R. (2016). "Safety implementation framework for Pakistani construction industry." *Safety Science*, 82, 301-314.

Rajaprasad, S.V.S., and Chalapathi, P.V. (2015). "Factors influencing implementation of OHSAS 18001 in Indian construction organizations: Interpretive structural modeling approach." *Safety and Health at Work*, 6(3), 200-205.

Reason, J. (2016). "Managing the risks of organizational accidents." Routledge Press, London.

Reason, J. (2000). "Human error: Models and management." *BMJ: British Medical Journal*, 320(7237), 768-770.

Reiman, T., and Rollenhagen, C. (2014). "Does the concept of safety culture help or hinder systems thinking in safety?." *Accident Analysis & Prevention*, 68, 5-15.

Reinartz, W., Haenlein, M., and Henseler, J. (2009). "An empirical comparison of the efficacy of covariance-based and variance-based SEM." *International Journal of Research in Marketing*, 26, 332–344.

Remawi, H., Bates, P., and Dix, I. (2011). "The relationship between the implementation of a safety management system and the attitudes of employees towards unsafe acts in aviation." *Safety Science*, 49(5), 625-632.

Rõa, K. and Merisalu E. (2010). "Economic analysis of occupational health and safety in Estonian enterprises." *Barents Newsletter on Occupational Health and Safety*, 13(2010), 89-91.

Robins, J. (2012). "Partial-least squares." *Long Range Planning*, 5(45), 309-311.

Roldan, J.L. and Sanchez-Franco, M.J. (2012). "Variance based structural equation modelling: Guidelines for using partial least squares in information systems research." *Research methodologies, innovations and philosophies in software systems engineering and information systems*, 10, 193–221.

Rooke, J., and Clark, L. (2005). "Learning, knowledge and authority on site: A case study of safety practice." *Building Research & Information*, 33(6), 561-570.

Saedi, A.M., Majid, A.A., and Isa, Z. (2019). "Evaluation of safety climate differences among employees' demographic variables: A cross-sectional study in two different-sized manufacturing industries in Malaysia." *International Journal of Occupational Safety and Ergonomics*, 1-30.

Safitri, D.M., Mediana, A., and Septiani, W. (2019). "Measuring influence from safety climate to safety behavior in bus rapid transit drivers." *IOP Conference Series: Materials Science and Engineering*, 528 (1), 012008.

Saunders, M., Lewis, P., and Thornhill, A. (2009). "Research Methods for Business Students." Pearson Education India.

Schein, E.H. (1992). "Organizational Culture and Leadership." Jossey-Bass, San Francisco, USA.

Schulte, P.A., Lentz, T.J., Anderson, V.P. and Lamborg, A.D. (2004). "Knowledge management in occupational hygiene: The United States example." *Annals of Occupational Hygiene*, 48(7), 583-594.

Schwatka, N.V., Hecker, S., and Goldenhar, L.M. (2016). "Defining and measuring safety climate: A review of the construction industry literature." *Annals of Occupational Hygiene*, 60(5), 537-550.

Seo, D.C. (2005). "An explicative model of unsafe work behavior." *Safety science*, 43(3), 187-211.

Seo, D.C., Torabi, M.R., Blair, E.H., and Ellis, N.T. (2004). "A cross-validation of safety climate scale using confirmatory factor analytic approach." *Journal of Safety Research*, 35(4), 427-445.

Seo, H.C., Lee, Y.S., Kim, J.J., and Jee, N.Y. (2015). "Analysing safety behaviours of temporary construction workers using structural equation modelling." *Safety Science*, 77, 160-168.

Shah, N. (2011). "Ethical issues in biomedical research and publication." *Journal of Conservative Dentistry*, 14(3), 205–207.

Shan, M., Chan, A.P., Le, Y., and Hu, Y. (2015). "Investigating the effectiveness of response strategies for vulnerabilities to corruption in the Chinese public construction sector." *Science and Engineering Ethics*, 21(3), 683-705.

Shea, T., De Cieri, H., Donohue, R., Cooper, B., and Sheehan, C. (2016). "Leading indicators of occupational health and safety: An employee and workplace level validation study." *Safety Science*, 85, 293-304.

Shen, Y., Tuuli, M.M., Xia, B., Koh, T.Y., and Rowlinson, S. (2014). "Toward a model for forming psychological safety climate in construction project management." *International Journal of Project Management*, 33(1), 223-235.

Sherehiy, B., and Karwowski, W. (2006). "Knowledge management for occupational safety, health, and ergonomics." *Human Factors and Ergonomics in Manufacturing & Service Industries*, 16(3), 309-319.

Shi, L., Ye, K., Lu, W., and Hu, X. (2014). "Improving the competence of construction management consultants to underpin sustainable construction in China." *Habitat International*, 41, 236-242.

Shih, B.Y., Chen, C.Y. and Chen, Z.S. (2013). "An empirical study of an internet marketing strategy for search engine optimization." *Human Factors and Ergonomics in Manufacturing and Service Industries*, 23(6), 528-540.

Shoji, T., and Egawa, Y. (2006). "The structure of safety climates and its effects on workers' attitudes and work safety at Japanese construction work sites." *Journal of UOEH*, 28(1), 29-43.

Silva, S., and Lima, M.L. (2005). "Safety as an organizational value: Improving safety practices." *Advances in Safety and Reliability*, 1817-1824.

Simukonda, W., Manu, P., Mahamadu, A.M., and Dziekonski, K. (2018). "Occupational safety and health management in developing countries: A study of construction companies in Malawi." *International Journal of Occupational Safety and Ergonomics*, 1-16.

Siu, O.L., Phillips, D.R., and Leung, T.W. (2004). "Safety climate and safety performance among construction workers in Hong Kong: The role of psychological strains as mediators." *Accident Analysis and Prevention*, 36(3), 359-366.

Sneed, J., and Henroid Jr, D. (2007). "Impact of educational interventions on Hazard Analysis Critical Control Point (HACCP) program implementation in Iowa schools." *The Journal of Child Nutrition and Management*, 31(1), 1-14.

Sokas, R.K., Jorgensen, E., Nickels, L., Gao, W., and Gittleman, J.L. (2009). "An intervention effectiveness study of hazard awareness training in the construction building trades." *Public Health Reports*, 124(4_suppl1), 161-168.

Sorensen, J.N. (2002). "Safety culture: A survey of the state-of-the-art." *Reliability Engineering and System Safety*, 76(2), 189-204.

Sparer, E.H., Murphy, L.A., Taylor, K.M., and Dennerlein, J.T. (2013). "Correlation between safety climate and contractor safety assessment programs in construction." *American Journal of Industrial Medicine*, 56(12), 1463-1472.

Srinivasan, R. and Lohith, C.P. (2017). "Strategic marketing and innovation for Indian MSMEs." Springer Nature, Singapore.

Stiles, J. (2003). "A philosophical justification for a realist approach to strategic alliance research." *Qualitative Market Research: An International Journal*, 6(4), 263-271.

Subramaniama, C., Shamsudinb, F.M., and Alshuaibic, A.S.I. (2017). "Investigating employee perceptions of workplace safety and safety compliance using PLS-SEM among technical employees in Malaysia." *Journal of Applied Structural Equation Modeling*, 1(1), 44-61.

Sunindijo, R.Y., and Zou, P.X. (2012). "How project manager's skills may influence the development of safety climate in construction projects." *International Journal of Project Organisation and Management*, 4(3), 286-301.

Sunindijo, R.Y., and Zou, P.X. (2013). "Conceptualizing safety management in construction projects." *Journal of Construction Engineering and Management*, 139(9), 1144-1153.

Tabachnick, B.G., and Fidell, L.S. (2007). "Using multivariate statistics." Pearson Education, Boston, USA.

Templeton, K. (2014), "Effectiveness of the near miss safety program relative to the total number of recordable accidents in a manufacturing facility", M.Sc. thesis, Old Dominion University, Virginia, USA.

Tenenhaus, M., Vinzi, V.E., Chatelin, Y.M., and Lauro, C. (2005). "PLS path modeling." *Computational Statistics and Data Analysis*, 48(1), 159-205.

Teo, E.A.L. and Feng, Y. (2011). "The indirect effect of safety investment on safety performance for building projects." *Architectural Science Review*, 54(1), 65-80.

Teperi, A.M., Lappalainen, J., Puro, V., and Perttula, P. (2019). "Assessing artefacts of maritime safety culture-current state and prerequisites for improvement." *WMU Journal of Maritime Affairs*, 18(1), 79-102.

Tholén, S.L., Pousette, A., and Törner, M. (2013). "Causal relations between psychosocial conditions, safety climate and safety behaviour: A multi-level investigation." *Safety Science*, 55, 62-69.

Thompson, R.C., Hilton, T.F. and Witt, L.A. (1998). "Where the safety rubber meets the shop floor: A confirmatory model of management influence on workplace safety." *Journal of Safety Research*, 29(1), 15-24.

Tongco, M.D.C. (2007). "Purposive sampling as a tool for informant selection." *Ethno Botany Research and Applications*, 5, 147-158.

Trethewy, R.W. (2003). "OHS performance: Improved indicators for construction contractors." *Journal of Construction Research*, 4(1), 17-27.

Trinh, M.T., Feng, Y., and Mohamed, S. (2018). "Framework for measuring resilient safety culture in Vietnam's construction environment." *Journal of Construction Engineering and Management*, 145(2), 04018127.

Tripathi, K.K. and Jha, K.N. (2017). "Determining success factors for a construction organization: A structural equation modelling approach." *Journal of Management in Engineering*, 34(1), 04017050.

Turner, B.A., Pidgeon, N., Blockley, D., and Toft, B. (1989). "Safety culture: Its importance in future risk management." *Second World Bank Workshop on Safety Control and Risk Management*, Karlstad, Sweden, 6-9.

Umar, T., and Egbu, C. (2018). "Perceptions on safety climate: A case study in the Omani construction industry." *Proceedings of the ICE-Management, Procurement and Law*, 171(6), 251-263.

Valler, M., and Virovere, A. (2010). "Structural capital as the success factor: Using intellectual capital to increase the competitiveness." *LOP LAMBERT Academic Publishing*, 69.

van Nunen, K., Li, J., Reniers, G., and Ponnet, K. (2018). "Bibliometric analysis of safety culture research." *Safety Science*, 108, 248-258.

van Nunen, K., Reniers, G., and Ponnet, K. (2018). "Measuring and improving safety culture in organisations: An exploration of tools developed and used in Belgium." *Journal of Risk Research*, 21(5), 622-644.

Vecchio-Sadus, A.M. and Griffiths, S. (2004), "Marketing strategies for enhancing safety culture." *Safety Science*, 42(7), 601-619.

Venkata-Siva-Raja-Prasad, S., Prasada-Rao, Y., and Venkata-Chalapathi, P. (2013). "Prioritizing the elements of OHSAS-18001 in construction segments in India–AHP approach." *International Journal of Occupational Hygiene*, 5(4), 159-165.

Vinodkumar, M.N., and Bhasi, M. (2011). "A study on the impact of management system certification on safety management." *Safety Science*, 49(3), 498-507.

Wang, F., Ding, L., Love, P.E., and Edwards, D.J. (2016). "Modelling tunnel construction risk dynamics: Addressing the production versus protection problem." *Safety Science*, 87, 101-115.

Wetzel, E.M., and Thabet, W.Y. (2015). "The use of a BIM-based framework to support safe facility management processes." *Automation in Construction*, 60, 12-24.

Wetzels, M., Odekerken-Schroder, G., and van Oppen, C. (2009). "Using PLS path modeling for assessing hierarchical construct models: Guidelines and empirical illustration." *MIS Quarterly*, 33(1), 177–195.

Williams, B., Onsman, A., and Brown, T. (2010). "Exploratory factor analysis: A five-step guide for novices." *Australasian Journal of Paramedicine*, 8(3).

Williamson, A.M., Feyer, A.M., Cairns, D., and Biancotti, D. (1997). "The development of a measure of safety climate: The role of safety perceptions and attitudes." *Safety Science*, 25(1-3), 15-27.

Wu, C., Fang, D., and Li, N. (2015). "Roles of owners' leadership in construction safety: The case of high-speed railway construction projects in China." *International Journal of Project Management*, 33(8), 1665-1679.

Wu, C., Song, X., Wang, T., and Fang, D. (2015). "Core dimensions of the construction safety climate for a standardized safety-climate measurement." *Journal of Construction Engineering and Management*, 141(8), 04015018.

Yin, R.K. (2009). "Case Study Research Design and Methods." *Applied Social Research Methods Series*, Sage Publications, Thousand Oaks, London, UK.

Zahoor, H. (2016). "Investigating the relationship between safety climate and safety performance in the construction of multi-storey buildings in Pakistan." Doctoral thesis, Hong Kong Polytechnic University, Hong Kong.

Zahoor, H., Chan, A.P., Utama, W.P., Gao, R., and Memon, S. A. (2017). "Determinants of safety climate for building projects: SEM-based cross-validation study." *Journal of Construction Engineering and Management*, 143(6), 05017005.

Zhang, L., Liu, Q., Wu, X. and Skibniewski, M. J. (2016). "Perceiving interactions on construction safety behaviours: Workers' perspective." *Journal of Management in Engineering*, 32(5), 04016012.

Zhang, S., Boukamp, F., and Teizer, J. (2015). "Ontology-based semantic modeling of construction safety knowledge: Towards automated safety planning for job hazard analysis (JHA)." *Automation in Construction*, 52, 29-41.

Zhou, Q., Fang, D., and Mohamed, S. (2010). "Safety climate improvement: Case study in a Chinese construction company." *Journal of Construction Engineering and Management*, 137(1), 86-95.

Zhou, Q., Fang, D., and Wang, X. (2008). "A method to identify strategies for the improvement of human safety behaviour by considering safety climate and personal experience." *Safety Science*, 46(10), 1406-1419.

Zhou, Z., Goh, Y.M., and Li, Q. (2015). "Overview and analysis of safety management studies in the construction industry." *Safety Science*, 72, 337–350.

Zohar, D. (1980). "Safety climate in industrial organizations: Theoretical and applied implications." *Journal of Applied Psychology*, 65(1), 96.

Zohar, D. (2010), “Thirty years of safety climate research: Reflections and future directions”, *Accident Analysis & Prevention*, 42(5), 1517-1522.

Annexure-A:

Systematic literature review of codified safety culture articles

List of codified articles (51 articles)

Safety Science (SS) (n=27)

- Glendon and Litherland, (2001)
- Choudhry et al., (2007)
- Dingsdag et al., (2008)
- Dov, (2008)
- Jaselskis et al., (2008)
- Larsson et al., (2008)
- Meliá et al., (2008)
- Zhou et al., (2008)
- Mohamed et al., (2009)
- Cambraia et al., (2010)
- Borys, (2012)
- Ismail et al., (2012)
- Biggs and Biggs, (2013)
- Biggs et al., (2013)
- Cheng and Wu, (2013)
- Cigularov, et al., (2013b)
- Colley et al., (2013)
- Fang and Wu, (2013)
- Feng, (2013)
- Li et al., (2015)
- Seo et al., (2015)
- Zhou et al., (2015)
- Patel and Jha, (2016)
- Raheem and Issa, (2016)
- Wang et al., (2016)
- Ajslev et al., (2017)
- Li et al., (2017)

Journal of Construction Engineering and Management (ASCE) (n=16)

- Mohamed, (2002)
- Mohamed, (2003)
- Fang et al., (2006)
- Chen et al., (2009)
- Choudhry et al., (2009)
- Molenaar et al., (2009)
- Zhou et al., (2010)
- Chen and Jin, (2011)
- Gilkey et al., (2011)
- Chen and Jin, (2012)
- Hon et al., (2012)
- Chen et al., (2013)
- Sunindijo and Zou, (2013)
- Patel and Jha, (2014)
- Wu et al., (2015)
- Gao et al., (2016)

Journal of Management in Engineering (JME) (n=7)

- Choudhry et al., (2007)
- Hon and Chan, (2013)
- Liao et al., (2013)
- Patel and Jha, (2014)
- Fang et al., (2015)
- Patel and Jha, (2016)
- Akroush and El-adaway, (2017)

Automation in Construction (AC) (n=1)

- Wetzel and Thabet, (2015)

Journal papers (51 articles)

Ajslev, J., Dastjerdi, E.L., Dyreborg, J., Kines, P., Jeschke, K C., Sundstrup, E., and Andersen, L.L. (2017). "Safety climate and accidents at work: Cross-sectional study among 15,000 workers of the general working population." *Safety Science*, 91, 320-325.

Akroush, N.S., and El-adaway, I.H. (2017). "Utilizing construction leading safety indicators: Case study of Tennessee." *Journal of Management in Engineering*, 33(5), 06017002.

Biggs, H.C., and Biggs, S.E. (2013). "Interlocked projects in safety competency and safety effectiveness indicators in the construction sector." *Safety Science*, 52, 37-42.

Biggs, S.E., Banks, T.D., Davey, J.D., and Freeman, J.E. (2013). "Safety leaders' perceptions of safety culture in a large Australasian construction organisation." *Safety Science*, 52, 3-12.

Borys, D. (2012). "The role of safe work method statements in the Australian construction industry." *Safety Science*, 50(2), 210-220.

Cambraia, F.B., Saurin, T.A., and Formoso, C.T. (2010). "Identification, analysis and dissemination of information on near misses: A case study in the construction industry." *Safety Science*, 48(1), 91-99.

Chen, P., Partington, D., and Qiang, M. (2009). "Cross-cultural understanding of construction project managers' conceptions of their work." *Journal of Construction Engineering and Management*, 135(6), 477-487.

Chen, Q., and Jin, R. (2011). "Safety4Site commitment to enhance jobsite safety management and performance." *Journal of Construction Engineering and Management*, 138(4), 509-519.

Chen, Q., Jin, R., 2012. Multilevel safety culture and climate survey for assessing new safety program. *Journal of Construction Engineering and Management*, 139(7), pp.805-817.

Chen, Q., Jin, R., and Soboyejo, A. (2013). "Understanding a contractor's regional variations in safety performance." *Journal of Construction Engineering and Management*, 139(6), 641-653.

Cheng, C.W., and Wu, T.C. (2013). "An investigation and analysis of major accidents involving foreign workers in Taiwan's manufacture and construction industries." *Safety Science*, 57, 223-235.

Choudhry, R.M., Fang, D., and Lingard, H. (2009). "Measuring safety climate of a construction company." *Journal of Construction Engineering and Management*, 135(9), 890-899.

Choudhry, R.M., Fang, D., and Mohamed, S. (2007). "Developing a model of construction safety culture." *Journal of Management in Engineering*, 23(4), 207-212.

Choudhry, R.M., Fang, D., and Mohamed, S. (2007). "The nature of safety culture: A survey of the state-of-the-art." *Safety Science*, 45(10), 993-1012.

Cigularov, K.P., Lancaster, P.G., Chen, P.Y., Gittleman, J., and Haile, E. (2013). "Measurement equivalence of a safety climate measure among Hispanic and white Non-Hispanic construction workers." *Safety Science*, 54, 58-68.

Colley, S.K., Lincolne, J., and Neal, A. (2013). "An examination of the relationship amongst profiles of perceived organizational values, safety climate and safety outcomes." *Safety Science*, 51(1), 69-76.

Dingsdag, D.P., Biggs, H.C., and Sheahan, V.L. (2008). "Understanding and defining OH&S competency for construction site positions: Worker perceptions." *Safety Science*, 46(4), 619-633.

Dov, Z. (2008). "Safety climate and beyond: A multi-level multi-climate framework." *Safety Science*, 46(3), 376-387.

Fang, D., Chen, Y., and Wong, L. (2006). "Safety climate in construction industry: A case study in Hong Kong." *Journal of Construction Engineering and Management*, 132(6), 573-584.

Fang, D., Wu, C., and Wu, H. (2015). "Impact of the supervisor on worker safety behaviour in construction projects." *Journal of Management in Engineering*, 31(6), 04015001.

Fang, D., and Wu, H. (2013). "Development of a Safety Culture Interaction (SCI) model for construction projects." *Safety Science*, 57, 138-149.

Feng, Y. (2013). "Effect of safety investments on safety performance of building projects." *Safety Science*, 59, 28-45.

Gao, R., Chan, A.P., Utama, W.P., and Zahoor, H. (2016). "Workers' perceptions of safety climate in international construction projects: Effects of nationality, religious belief, and employment mode." *Journal of Construction Engineering and Management*, 143(4), 04016117.

Gilkey, D.P., del Puerto, C.L., and Keefe, T. (2011). "Comparative analysis of safety culture perceptions among homesafe managers and workers in residential construction." *Journal of Construction Engineering and Management*, 138(9), 1044-1052.

Glendon, A.I., and Litherland, D.K. (2001). "Safety climate factors, group differences and safety behaviour in road construction." *Safety Science*, 39(3), 157-188.

Hon, C.K., and Chan, A.P. (2013). "Safety management in repair, maintenance, minor alteration, and addition works: Knowledge management perspective." *Journal of Management in Engineering*, 30(6), 04014026.

Hon, C. K., Chan, A. P., Yam, M. C., 2012. Determining safety climate factors in the repair, maintenance, minor alteration, and addition sector of Hong Kong. *Journal of Construction Engineering and Management*, 139(5), pp.519-528.

Ismail, Z., Doostdar, S., and Harun, Z. (2012). "Factors influencing the implementation of a safety management system for construction sites." *Safety Science*, 50(3), 418-423.

Jaselskis, E.J., Strong, K.C., Aveiga, F., Canales, A.R., and Jahren, C. (2008). "Successful multi-national workforce integration program to improve construction site performance." *Safety Science*, 46(4), 603-618.

Larsson, S., Pousette, A., and Törner, M. (2008). "Psychological climate and safety in the construction industry-mediated influence on safety behaviour." *Safety Science*, 46(3), 405-412.

Li, H., Lu, M., Hsu, S.C., Gray, M., and Huang, T. (2015). "Proactive behaviour-based safety management for construction safety improvement." *Safety Science*, 75, 107-117.

Li, Q., Ji, C., Yuan, J., and Han, R. (2017). "Developing dimensions and key indicators for the safety climate within China's construction teams: A questionnaire survey on construction sites in Nanjing." *Safety Science*, 93, 266-276.

Liao, P.C., Lei, G., Xue, J., and Fang, D. (2013). "Influence of person-organizational fit on construction safety climate." *Journal of Management in Engineering*, 31(4), 04014049.

Meliá, J.L., Mearns, K., Silva, S.A., and Lima, M.L. (2008). "Safety climate responses and the perceived risk of accidents in the construction industry." *Safety Science*, 46(6), 949-958.

Mohamed, S. (2002). "Safety climate in construction site environments." *Journal of Construction Engineering and Management*, 128(5), 375-384.

Mohamed, S. (2003). “Scorecard approach to benchmarking organizational safety culture in construction.” *Journal of Construction Engineering and Management*, 129(1), 80–88.

Mohamed, S., Ali, T.H., and Tam, W.Y.V. (2009). “National culture and safe work behaviour of construction workers in Pakistan.” *Safety Science*, 47(1), 29-35.

Molenaar, K.R., Park, J.I., and Washington, S. (2009). “Framework for measuring corporate safety culture and its impact on construction safety performance.” *Journal of Construction Engineering and Management*, 135(6), 488-496.

Patel, D.A., and Jha, K.N. (2014). “Neural network approach for safety climate prediction.” *Journal of Management in Engineering*, 31(6), 05014027.

Patel, D. A. and Jha, K.N. (2014). “Neural network model for the prediction of safe work behaviour in construction projects.” *Journal of Construction Engineering and Management*, 141(1), 04014066.

Patel, D.A., and Jha, K.N. (2016). “Evaluation of construction projects based on the safe work behaviour of co-employees through a neural network model.” *Safety Science*, 89, 240-248.

Patel, D.A., and Jha, K.N. (2016). “Structural equation modelling for relationship-based determinants of safety performance in construction projects.” *Journal of Management in Engineering*, 32(6), 05016017.

Raheem, A.A., and Issa, R.R. (2016). “Safety implementation framework for Pakistani construction industry.” *Safety Science*, 82, 301-314.

Seo, H.C., Lee, Y.S., Kim, J.J., and Jee, N.Y. (2015). “Analysing safety behaviours of temporary construction workers using structural equation modelling.” *Safety Science*, 77, 160-168.

Sunindijo, R.Y., and Zou, P.X. (2013). “Conceptualizing safety management in construction projects.” *Journal of Construction Engineering and Management*, 139(9), 1144-1153.

Wang, F., Ding, L., Love, P.E., and Edwards, D.J. (2016). “Modelling tunnel construction risk dynamics: Addressing the production versus protection problem.” *Safety Science*, 87, 101-115.

Wetzel, E.M., and Thabet, W.Y. (2015). “The use of a BIM-based framework to support safe facility management processes.” *Automation in Construction*, 60, 12-24.

Wu, C., Song, X., Wang, T., and Fang, D. (2015). “Core dimensions of the construction safety climate for a standardized safety-climate measurement.” *Journal of Construction Engineering and Management,* 141(8), 04015018.

Zhou, Q., Fang, D., and Mohamed, S. (2010). “Safety climate improvement: Case study in a Chinese construction company.” *Journal of Construction Engineering and Management,* 137(1), 86-90

Zhou, Q., Fang, D., and Wang, X. (2008). “A method to identify strategies for the improvement of human safety behaviour by considering safety climate and personal experience.” *Safety Science,* 46(10), 1406-1419.

Zhou, Z., Goh, Y.M., and Li, Q. (2015). “Overview and analysis of safety management studies in the construction industry.” *Safety Science*, 72, 337–350.

Annexure-B:

Permission letter to use knowledge-based safety culture survey instrument (Ethical consideration)

सिविल अभियान्त्रिक विभाग
राष्ट्रीय प्रौध्योगिकी संस्थान कर्नाटक, सुरत्कल
पोस्ट श्रीनिवासनगर, मंगलूरु - 575 025
DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL
POST SRINIVASNAGAR, MANGALURU - 575 025

Date: 16/02/2018

To Whom It May Concern

Subject: Seeking permission to conduct questionnaire survey

Mr. Deepak M.D. is carrying out his Ph.D. research on *Knowledge Management for Safety Culture - An Integrated Framework for Construction Industry* under the supervision of Dr. Gangadhar Mahesh, Assistant professor, Department of civil engineering, NITK Surathkal, Karnataka, India.

The objective of the study is to integrate knowledge management dimension into safety management practices for improving safety culture of construction industry. For achieving this, a questionnaire survey is formulated which requires your valuable response.

All collected data or information from the survey will be kept confidential and used only for research purpose.

Looking forward for your positive response.

Regards,

Deepak M.D.
Roll no: CV15F15

Forwarded:

DEPT. OF CIVIL ENGG.

(Research supervisor)
Dr. Gangadhar Mahesh
Assistant professor
Department of civil engineering,
NITK Surathkal, Karnataka, India

Faculty in Civil Engineering
National Institute of Technology Karnataka, Surathkal
Mangalore - 575 025, Karnataka, INDIA

टेलिफाक्स (Fax) : +91-824-2474039
E-mail : hodcivil@nitk.ac.in
Web. : www.nitk.ac.in
दूरभाष (Ph) : +91-824-2474000, विस्तार (Extn.) : 3041
+91-824-2474051 सीधा (Direct)

CEO
Confederation of Real Estate Developers' Associations of India
(CREDAI) - Karnataka.

Deepak M.D.
Research Scholar,
Department of Civil Engineering,
National Institute of Technology-Karnataka,
Surathkal, Mangalore, Karnataka, India

Respected Sir,

Subject: Request for Conducting Questionnaire Survey

I am a Research scholar from civil engineering department at National Institute of Technology-Karnataka, India.

I am truly envisioned by the works of Confederation of Real Estate Developers' Associations of India (CREDAI) towards health and safety in Indian construction industry.

The research work undertaken primarily focuses on improving health and safety culture of Indian construction industry. So, as a part of the research work a questionnaire survey is formulated on the topic '*Knowledge Management for Safety Culture - An Integrated Framework for Construction Industry'*.

In this regard, I require your permission to collect responses for the survey from the **Registered Members of Confederation of Real Estate Developers' Associations of India (CREDAI) chapters of Karnataka state.**

All information provided will be treated strictly as confidential and purely used for research purpose. If you would be interested in greater detail, you will receive a copy of the executive summary after collecting the necessary responses.

Your approval to conduct this study will be greatly appreciated. Thank you in advance for your interest and assistance with this research.

Sincerely,

Deepak M.D.
Ph. no: +919663844738
Email id: deepakmd.md@gmail.com

Construction Industry Development Council
(CIDC)
New Delhi.

Deepak M.D.
Research Scholar,
Department of Civil Engineering,
National Institute of Technology-Karnataka,
Surathkal, Mangalore, Karnataka, India

Respected Sir,

Subject: Request for Conducting Questionnaire Survey

I am a Research scholar from civil engineering department at National Institute of Technology-Karnataka, India.

I am truly envisioned by the works of Construction Industry Development Council (CIDC) towards health and safety in Indian construction industry.

The research work undertaken primarily focuses on improving health and safety culture of Indian construction industry. So, as a part of the research work a questionnaire survey is formulated on the topic '*Knowledge Management for Safety Culture - An Integrated Framework for Construction Industry'*.

In this regard, I require your permission to collect responses for the survey from the **Registered Members of Construction Industry Development Council (CIDC)**.

All information provided will be treated strictly as confidential and purely used for research purpose. If you would be interested in greater detail, you will receive a copy of the executive summary after collecting the necessary responses.

Your approval to conduct this study will be greatly appreciated. Thank you in advance for your interest and assistance with this research.

Sincerely,

Deepak M.D.
Ph. no: +919663844738
Email id: deepakmd.md@gmail.com

Annexure-C:

Questionnaire survey to integrate Knowledge management aspects in Safety culture of construction industry

Purpose of study and information about the survey

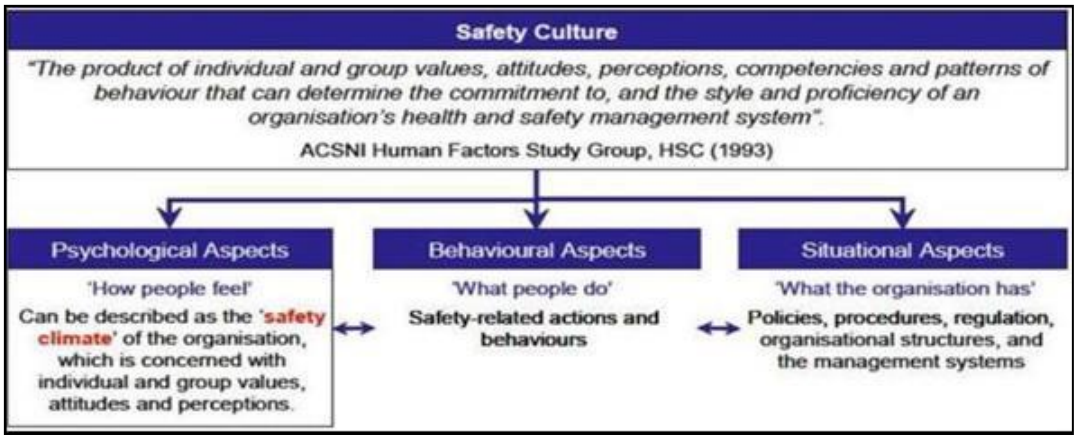
An important contribution to avoid accidents and the associated costs at the workplace is to have a well-defined and effective implementation of Occupational Health and Safety culture. The process of knowledge management supports the development of Occupational Health and Safety culture in the organization.

The objective of the study is to integrate knowledge management dimension into safety management practices for improving safety culture in the construction industry. This research aims to identify the factors required for development of knowledge dimension for safety culture in construction industry. Since the development of safety culture is meant for the improvement of the safety performance, it requires the understanding of the influencing factors for the development of safety knowledge.

Definitions of most commonly words used in the study are:

- Safety culture is a reflection of attitudes, beliefs, perception and values that employees share in relation to safety in an organization.
- Knowledge Management is the concept of finding, gathering, assessing, organizing, and sharing information or knowledge.
- Safety knowledge can be conceptualized as an employee's understanding of the safety procedures within an organization.

The measure of safety culture addresses the reciprocal relations existing between psychological, behavioural and situational aspects. Factors affecting safety knowledge under each of these aspects are formulated in the questionnaire survey.



Survey details

The questionnaire covers the following sections:

Section A - Background information: This section provides general information about the respondent and information about the company.

Section B - Measuring safety aspects in construction industry: This section focuses on evaluating the factors that influence safety knowledge which in turn impacts safety culture in construction industry.

The following sections highlight the dimensions of safety culture where focus is required on how these factors influence knowledge management in construction industry.

Section B1 – Psychological aspects of safety culture
Section B2 – Behavioural aspects of safety culture
Section B3 – Organizational aspects of safety culture
Section B4 – Knowledge Management aspects of safety culture
Section B5 – Factors enhancing safety culture in the organization

Section A: Background Information

Personal Information	
Name:	
Gender:	
Email id:	
Contact number:	

Company Information	
Name of the company/organization:	
Designation:	
Experience in years:	
Company type: (Client/Owner, Main contractor, Subcontractor, Consultant, Others)	
Size of the company/organization: [Small (Less than 200 employees) Medium (200-500 employees) Large (More than 500 employees)]	
Is the company OHSAS 18001:2007 certified?	

Section B: Safety Culture and its Aspects

This section focuses on evaluating the factors that influence safety knowledge in construction industry. The following sections highlight the dimensions of safety culture where focus is required on how these factors influence knowledge management in construction industry.

Section B1: Psychological Aspects of Safety Culture

In this section, factors on *psychological (personal)* aspects that impact safety knowledge in construction industry are formulated. Rate against each of them by indicating the degree of their importance.

Note: Likert scale ratings,

1 = Not important
2 = Of little importance
3 = Moderately important
4 = Important
5 = Very Important

PSYCHOLOGICAL FACTORS					
QUESTION - FROM YOUR EXPERIENCE, HOW INFLUENCING DO THE FOLLOWING PSYCHOLOGICAL FACTORS IMPROVES SAFETY CULTURE IN CONSTRUCTION INDUSTRY?					
Factors under consideration	**Degree of importance**				
	1 Not important	**2** Of little importance	**3** Moderately important	**4** Important	**5** Very Important
Personal commitment to safety is most important thing for an individual at work					
Job satisfaction related to safety actions influences safety culture at workplace					
Relationship among co-workers impacts safety at workplace					
Culture, language and background of an individual affects safety culture					
Adaptability to new systems significantly influence employees' perception on safety culture *(Information: Management of change is a part of safety management, however, adaptability to new system significantly affect the employees' perception on safety culture)*					

Employees actions that **comply with safety standards** of the organization builds safety culture in the organization					
Co-worker's **personality and willingness to share safety-related information** fosters safety culture					
Adequate **safety knowledge and training competence** is necessary for enhancing safety knowledge at workplace *(Information: Competence can be described as the combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task safely)*					
Financial incentives are provided to necessitate safety knowledge sharing process					
Involvement in **identifying the potential safety hazards** that causes harm to workers health and safety is important to improve safety culture					
Involvement in or exposure to safety related issues promotes physical experience at job sites					
Participation or involvement of an employee in safety-performance evaluation process develops safety culture in an organization					
Occupational Health & Safety expertise (OH&S) influences on workplace safety *(Information: An expert who has diverse skills to work in all hazard classes and provide a solid foundation for working with complex safety related issues)*					
Safety mentoring process supports an enterprise-wide culture of safety (*Information: Safety Mentoring is a process that provides ongoing knowledge transfer achieved through a developmental partnership in which one person shares knowledge with others*)					
Any others (please specify and rate accordingly):					

Section B2: Behavioural Aspects of Safety Culture

In this section, factors on *behavioural (job-related)* aspects that impact safety knowledge in construction industry are formulated. Rate against each of them by indicating the degree of their importance.

Note: Likert scale ratings,

1 = Not important
2 = Of little importance
3 = Moderately important
4 = Important
5 = Very Important

BEHAVIOURAL FACTORS					
QUESTION - FROM YOUR EXPERIENCE, HOW INFLUENCING DO THE FOLLOWING BEHAVIOURAL FACTORS IMPROVES SAFETY CULTURE IN CONSTRUCTION INDUSTRY?					
Factors under consideration	**Degree of importance**				
	1 Not important	**2** Of little importance	**3** Moderately important	**4** Important	**5** Very Important
Personal responsibility to safety actions induces safety culture in an organization					
Co-workers peer support towards safety related issues facilitate safety culture					
Team working encourages a strong sense among co-workers to improve safety culture					
Commitment to perform tasks and responsibilities ensures organization to achieve its goals					
Better and safe working environment for employees					
Effective safety communication tools necessitate proper communication to facilitate safety culture (Communication tools include: internet, intranet, tele-communications, social networks, videos and seminars etc.)					
Existence of safety plans for emergencies are useful to develop corrective action plans					
Internal safety department to monitor safety at projects in the organization develops safety culture					

Involvement in decision-making process related to safety formulates safety culture in an organization (*Information: Participation in the decision making process gives each employee the opportunity to voice their opinions, and to share their knowledge with others, thereby improving the relationship between manager and employee)*					
Time and contacts for safety develops knowledge sharing process in an organization					
Embedding safety knowledge management in the work process enables the best practices at workplace for organizations to build collaboration, knowledge capture, and knowledge sharing capabilities into existing processes and workflows					
Risk management helps to identify, assess, analyse and control the risk involved in the workplace					
Modelling the safe work practices in the job guides to achieve the standards of health and safety requirements					
Safety-Knowledge management program effectively aims to collect safety related information that builds organization knowledge					
Proprietary safety training through videos and demonstrations is essential for an individual at work to refresh and update knowledge					
Orientation and trainings are essential to do perform operations safely at workplace					
Any others (please specify and rate accordingly):					

Section B3: Organizational Aspects of Safety Culture

In this section, factors on *organizational (situational)* aspects that impact safety knowledge in construction industry are formulated. Rate against each of them by indicating the degree of their importance.

Note: Likert scale ratings,

1 = Not important
2 = Of little importance
3 = Moderately important
4 = Important
5 = Very Important

ORGANIZATIONAL FACTORS					
QUESTION - FROM YOUR EXPERIENCE, HOW INFLUENCING DO THE FOLLOWING ORGANIZATIONAL FACTORS IMPROVES SAFETY CULTURE IN CONSTRUCTION INDUSTRY?					
Factors under consideration	**Degree of importance**				
	1 Not important	**2** Of little importance	**3** Moderately important	**4** Important	**5** Very Important
Effective OH&S Management system helps to systematically manage health and safety in the workplace					
Well-established **Information Technology and Human Resource Management** fosters positive safety culture in organization					
The organization articulate a **clear vision and shared values** around safety that impacts safety culture					
Influence of leadership towards safety concerns at projects influence to achieve organizational safety goals					
Safety competence and proper training of managers facilitate safety culture in organization					
Clear visions of the objectives of safety knowledge management induces safety culture					
Being in accordance to **safety compliance** facilitate safety culture in an organizations					
Structured and systematic approach to **manage conflict** necessitate safety culture					
Management is supportive and committed towards handling safety related issues in the workplace					
Proper communication and feedback mechanism on safety related issues impacts safety culture					
Availability of **Communities of Practice** to handle safety problems at organization promotes safety culture in organization					

(*Information: Communities of practice is a group of people who share a personal and professional commitment to protect the safety and health of the employees in which they operate*)					
Safety planning implementation prevents accidents or incidents occurring at jobsite					
Allocation of safety resources promotes safety culture at workplace					
Regular discussion / meetings related to safety fosters safety culture at projects					
Organization training and safety programs develop safety knowledge of an individual					
Formalized process for **storing safety knowledge** provide necessary instructions to develop safe work practices and to accomplish work safely					
Safety performance metrics measures and improves overall safety performance of construction projects					
Existence of **safety knowledge sharing mechanism** helps to exchange safety related information, skills and expertise from employees of an organization					
Organization Safety-knowledge effectiveness helps to identify the deficient occupational health performance according to historically prior knowledge, and then make quick and effective responses					
Effective in storing safety matters in **organizational memory** builds safety knowledge management system					
Knowledge mapping tools for safety knowledge flow is essential for effective dissemination of resources towards the main components of the workplace system (*Information: Knowledge mapping is a tool for presenting where knowledge resides (e.g. people, media, organizational units or sources) and for demonstrating the patterns of knowledge flow)*					
Proper investment and budgetary requirements for effective safety knowledge management implementation to ensure a safe work environment					
Ease of access and retrieval of stored safety knowledge using database management tools facilitate safety culture practices at workplace					
Any others (please specify and rate accordingly):					

Section B4: Knowledge Management Aspects of Safety Culture

In this section, *Knowledge Management* factors that impact safety culture in construction industry are formulated. Rate against each of them by indicating the degree of their importance.

Note: Likert scale ratings,

1 = Not important
2 = Of little importance
3 = Moderately important
4 = Important
5 = Very Important

KNOWLEDGE MANAGEMENT FACTORS					
QUESTION - FROM YOUR EXPERIENCE, HOW INFLUENCING DO THE FOLLOWING KNOWLEDGE MANAGEMENT FACTORS IMPACT SAFETY CULTURE IN CONSTRUCTION INDUSTRY?					
Factors under consideration	**Degree of importance**				
	1 Not important	**2** Of little importance	**3** Moderately important	**4** Important	**5** Very Important
Maintaining accidents records helps to analyse the type and severity of accident occurring at workplace					
Safety regulations aids to prevent accidents or incidents at work place					
Following safety guidelines (rules and regulations) that comply with safety standards helps to understand and implement safety rules in organization					
Essential requirement of company records that conform with safety policies of the organization is necessary to promote safety culture at organizations					
Availability of safety databases facilitate safety culture in the organization					
Accident analysis and self-inspections at job is essential process with the objective of identifying any unsafe conditions at work place					

Comprehensive occupational health and safety policy builds safety vulture at work place					
Presence of integrated **safety documentation system** develop safety related information at construction projects					
Safety engineer's experience contributes to work safely					
Safety hazard recognition helps to take corrective actions (Examples of safety hazard - working at height, moving objects, slips, trips, and falls etc.)					
Relatedness to practical aspects of safety fosters safety culture at workplace					
Perceptual and cognitive skills to work safely influences safety culture (Examples: Decision-making capacity, perception, attention, memory, learning, reaction time, hazard detection etc.)					
Physical experience of an individual or group towards safety initiate safety culture at organization					
Clear understanding of thumb rules about safety improves safety culture (Example - Check for required Personal Protective Equipment PPE's at jobsite)					
Intuition and synthesis of safety facts and to apply them when necessary formulates safety culture					
Ability to learn and share values of an individual impact safety culture of organization					
Any others (please specify and rate accordingly):					

Section B5: Factors Enhancing Safety Culture in the Organization

The study also focuses on measuring the factors to enhance safety culture in the organization. Rate against each of them by indicating the degree of their importance.

Note: Likert scale ratings,

1 = Not important
2 = Of little importance
3 = Moderately important
4 = Important
5 = Very Important

Influence of Safety Culture in the organization	**Degree of importance**				
	1 Not important	**2** Of little importance	**3** Moderately important	**4** Important	**5** Very Important
From your experience, how do you perceive the influence of **Safety Culture** in reducing working accidents of construction industry?					
Enhancing Safety Culture in the organization From your experience, how do you perceive the following important factors to enhance safety culture in your organization?					
• Managing safety culture as a **change process**					
• Making sure the business follows relevant **safety culture initiatives**					
• Review of the **current practices of safety management** at the organization level					
• Defining **safety leadership roles and accountabilities**					
• Commitment towards **Occupational Health and Safety rules and regulations**					
• Importance of **safety certification** for improving safety culture in your organization					
Any others (please specify and rate accordingly):					

Annexure-D:

Knowledge-Based Safety Culture Assessment Framework

Indicate the level of importance by highlighting against each of the statement in the following table.

For example: "Maintaining accident records……" – If the level of importance is "Good", then the score of that factor is computed as (3.88 * 3 = 11.64) and this value is indicated in the Score column as "11.64".

The computation is done in similar way for all the factors in each of the dimension and the Total Score is computed.

The aggregate of Total Score is termed as "Safety Culture Score". This score indicates the level of safety culture in the organization.

Factors affecting knowledge-based safety culture	Level of importance				Score	Total
	Poor (value * 1)	Satisfactory (value * 2)	Good (value * 3)	Very Good (value * 4)		
Knowledge dimension						
Maintaining accidents records for analysing the type and severity of accident occurring at workplace	1.29	2.59	3.88	5.17		Subtotal 1
Following safety guidelines (rules and regulations) that comply with safety standards	1.26	2.52	3.78	5.04		
Essential requirement of company records that conform with safety policies of the organization	1.28	2.56	3.84	5.12		
Availability of safety databases in the organization	1.28	2.56	3.84	5.12		
Safety engineer's experience contributes to work safely	1.29	2.57	3.86	5.15		
Organizational dimension						
Safety competence and proper training of managers	1.26	2.51	3.77	5.02		
Being in accordance to safety compliance	1.24	2.49	3.73	4.98		
Allocation of safety resources whenever necessary	1.24	2.49	3.73	4.98		

Organization training and safety programs to develop safety knowledge	1.25	2.50	3.75	5.00		Subtotal 2
Organization Safety-knowledge effectiveness	1.26	2.51	3.77	5.03		
Behavioural dimension						
Better and safe working environment for employees	1.23	2.46	3.69	4.93		Subtotal 3
Existence of safety plans for emergencies	1.25	2.50	3.75	5.00		
Embedding safety knowledge management in the work process	1.23	2.47	3.70	4.93		
Proprietary safety training (videos and demonstrations)	1.25	2.50	3.75	5.00		
Orientation and trainings are essential to perform operations safely	1.24	2.48	3.71	4.95		
Psychological dimension						
Adaptability to new systems	1.24	2.48	3.72	4.95		Subtotal 4
Employee compliance towards safety standards	1.24	2.47	3.71	4.94		
Safety knowledge and training competence of employees	1.23	2.45	3.68	4.91		
Involvement in or exposure to safety related issues fosters physical experience	1.22	2.44	3.66	4.88		
Safety mentoring process	1.23	2.46	3.69	4.91		

Safety culture score = Subtotal 1 + Subtotal 2 + Subtotal 3 + Subtotal 4

Based on the above safety culture score, benchmarks are established as follows:

1. if the total safety culture score is between 25 and 100, the safety culture in the organization is poor;
2. if the total safety culture score is between 100 and 225, the safety culture in the organization is satisfactory; and
3. if the total safety culture score is between 225 and 400, the safety culture in the organization is good.

LIST OF CONFERENCES AND PUBLICATIONS

International Conference

Mahesh, G. and Deepak, M. D. (2017). "A conceptual model to integrate knowledge management dimension to develop an overall safety culture in construction industry." *Proceedings of the Special Sessions on Sociology of Structural Engineering and Construction Management*, 8th International Conference on Structural Engineering and Construction Management, Kandy, Sri Lanka, 1-9.

Journal Publications

Deepak, M. D. and Mahesh, G. (2019). "Developing a knowledge-based safety culture instrument for construction industry: Reliability and validity assessment in Indian context." *Journal of Engineering, Construction and Architectural Management*, 26 (11), 2597-2613. DOI: 10.1108/ECAM-09-2018-0383

Deepak, M. D., Mahesh, G. and Medi, N. (2019). "Knowledge management influence on safety management practices - Evidence from construction industry." *International Journal of Knowledge Management*, 15(4), 16-37. DOI: 10.4018/IJKM.2019100102

Deepak, M. D. and Mahesh, G. (2019). "Review of concepts and trends in safety culture research of construction industry." *Indian Journal of Public Health Research and Development*, 10(5), 174-178. DOI: 10.5958/0976-5506.2019.00985.9

Deepak, M. D. and Mahesh, G. (2020). "Influence of knowledge-based safety culture in construction industry: A stakeholder's perspective." *International Journal of Workplace Health Management* [Under review].

Book Chapter

Deepak, M. D. and Mahesh, G. (2020). "Systematic literature review of safety culture research and trends in construction industry." Edited Book on: *Secondary Research Methods in the Built Environment, published by Routledge: Taylor & Francis Group*. Editors: Dr Emmanuel Manu (Nottingham Trent University, Nottingham, UK) and Dr Julius Akotia (University of East London, London, UK) [Under review].

BIO-DATA

Deepak M.D.

Email: deepakmd.md@gmail.com

Contact no: +91-9663844738/8105242251

Address: #1144/A, 7th Cross, 6th Phase,

Sharadadevi Nagar, Mysuru-570022

Educational Background:

Degree	Year	Specialization	University/Institute
M.Tech.	2015	Construction Engineering and Management	Manipal Institute of Technology, Manipal University
B.E.	2013	Civil Engineering	National Institute of Engineering, Mysore

Employment Condition	Assistant Professor at National Institute of Construction Management and Research (NICMAR), Pune, Maharashtra, India