DEVELOPING A MODEL TO PREDICT UNSAFE BEHAVIOUR OF CONSTRUCTION WORKERS IN SRI LANKA

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Thesis submitted in partial fulfilment of the requirement for the degree of Master of Philosophy

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DECLARATION

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ABSTRACT

The construction industry is known to be one of the most accident-prone of work sectors around the globe. Although the construction output is less in Sri Lanka, compared to developed countries in general, the magnitude of the accident rate in the construction industry is significantly high. Most of the occupational accidents happen due to the unsafe behaviour of the workers. Along with this revelation, behaviour based safety has emerged as an effective approach to ensure occupational safety. The principal step of behaviour based safety approach involves the identification of the unsafe behaviour of the workers. The research, therefore, focused on investigating factors influencing construction workers' unsafe behaviour and developing a model to predict unsafe behaviour originated from those factors.

Quantitative research strategy was selected to carry out the study considering the nature of this investigation. The acts characterising the unsafe behaviour of construction workers, and the factors influencing those were identified through a literature survey. A pilot study was undertaken to validate and generalise the literature findings to the Sri Lankan construction industry. Fifteen unsafe acts those characterise the unsafe behaviour and fourteen factors those influence the unsafe behaviour were identified relevant to the local context. A survey approach was used to collect data. C1 grade building construction organisations were selected as the sampling framework. Twenty organisations were chosen within Colombo district to gather information from construction workers. The processed data were used to develop and train an Artificial Neural Network (ANN) predictive model that could predict unsafe behaviour of a construction worker with respect to a score.

Backpropagation architecture using Neuroph Studio software was employed to develop the predictive model. 277 data points taken from the survey were used to train the network. The architecture of the trained model was demonstrated by conducting a sensitivity analysis. Mean Absolute Error was the technique used in this process. Sensitivity analysis showed that the model is highly sensitive to the neuron corresponding to "education", while the lowest sensitivity was evident for the neuron corresponding to "employee involvement in safety". The results suggests that educational level of a worker has the highest influence on his unsafe behaviour at work. Similarly, the co-workers' involvement in safety on site has the lowest influence on unsafe behaviour of a worker. Furthermore, the predictive model was validated for generalisability using seven data points those were not used in training the network. The findings depict that the performance of the model is accurate due to high generalisation capabilities in the validation session. The model serve as a prototype tool to determine the unsafe behaviour level of construction workers and their safety training needs. This model can further be employed as a tool to proactively design interventions to avoid or minimise occupational accidents based on the unsafe behaviour levels of construction workers.

Keywords: Construction Industry, Construction Safety, Construction Worker, Unsafe Behaviour, Artificial Neural Networks.

To my parents…

ACKNOWLEDGMENT

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
ANN	Artificial Neural Networks
BBS	Behaviour Based Safety
BLS	Bureau of Labour Statistics
CIDA	Construction Industry Development Authority
EU-OSHA	European Agency for Safety and Health at work
HSE	Health and Safety Executive
ILO	International Labour Organization
IOSH	Institution of Occupational Safety and Health
MAE	Mean Absolute Error
RoSPA	Royal Society for the Prevention of Accidents
SMI	Serious Mental Illness
SPSS	Statistical Package for the Social Sciences
UK	United Kingdom
USA	United States of America
USBS	Unsafe Behaviour Score

CHAPTER 1

INTRODUCTION TO THE RESEARCH

CHAPTER 1

1. INTRODUCTION TO THE RESEARCH

1.1 Background

Occupational safety is among the important performance indicators at high performing organisations (Pawłowska, 2015). Despite the weight attached to the concept of occupational safety, a large number of accidents have been reported globally. For instance, an International Labour Organization (ILO) report estimated that two million occupational fatalities occur across the world every year (ILO, 2003). Further, the overall annual rate of occupational accidents, fatal and non-fatal, is estimated at 270 million (Hamalainen, Takala, & Saarela, 2006). Thus, The human, social and economic costs of occupational accidents, injuries and diseases and major industrial disasters have long been causing concerns at all levels from the individual workplace to the national and international (Alli, 2008). Measures and strategies designed to prevent, control, reduce or eliminate occupational hazards and risks have been developed and applied continuously over the years to keep pace with technological and economic changes. Despite continuous yet slow improvements, occupational accidents are still too frequent and their cost in terms of human suffering and economic burden continues to be significant (Alli, 2008).

The construction industry, being highly fragmented, marginalises the efforts to maintain safety standards and thus, is struggling to improve in the area of occupational safety (Gatti & Migliaccio, 2013; Jannadi & Bu-Khamsin, 2002). Compared with other industries; construction industry is always risky because of outdoor operations, work-at-heights, complicated on-site plants and equipment operation coupled with workers attitudes and behaviours towards safety (Choudhry & Fang, 2008). At site levels, construction activities are physically dispersed across various locations. Thus, supervising and monitoring safety issues in the workplace is much more challenging. Moreover, the rapidly changing nature of the construction industry exacerbates the situation (Jannadi & Bu-Khamsin, 2002; Wilson, 1989).

Thus the rates of fatal and nonfatal injuries and illnesses in the construction sector are relatively high (Abudayyeh, Fredericks, Butt, & Shaar, 2006). According to Liu (2013), a large number of construction accidents are reported, and thousands of workers are killed or injured on construction sites each year. For instance, 5,703 fatal and 3.9 million nonfatal workplace injuries were reported in the United States in 2006 (Bureau of Labour Statistics [BLS], 2007). Further, in the United Kingdom, the worker fatal injury rate in the construction sector was over 3.5 times the average rate across all industries (Health and Safety Executive [HSE], 2016). According to Gunawardena and Priyangika (2005, as cited in N. De Silva & Wimalaratne, 2012), Sri Lanka is considered to be one of the most vulnerable countries and is ranked at a low level for safety performance due to lack of improvement measures.

The nature of the work at construction sites in Sri Lanka is labour intensive and heavily depended on the workforce of skilled and unskilled with different educational backgrounds and hence has high potential for personal injuries (Gunawardena & Priyangika 2005; Rameezdeen, Pathirage, & Weerasooriya, 2003). Furthermore, the accident rate in the Sri Lankan construction industry is significantly higher than that of the developed countries such as United States of America (USA) (Chau et al., 2004), United Kingdom (UK) (HSE, 2016; Sacks, Rozenfeld, & Rosenfeld, 2009), Hong Kong (Siu, Phillips, & Leung, 2003), and Singapore (Chua & Goh, 2004). Though efforts have been made to address this problem, the results are far from satisfactory as construction accidents continue to dominate (Priyadarshani, Karunasena, & Jayasuriya, 2013).

The economic costs of these accidents and deaths are colossal, at the enterprise, national and global levels. Taking into account compensation, lost working time, interruption of production, training and retraining, medical expenses, and so on, estimates of these losses are routinely put at roughly 4% of global gross national product every year, and possibly much more (Alli, 2008). Abudayyeh et al. (2006) also explained that construction accidents directly impact the individuals involved, as well as on the work itself. These impacts include the personal suffering of the injured worker, construction delays, productivity losses, higher insurance premiums that result from accidents and the possible liability suits for all parties involved in the project. There are many other indirect impacts such as revenue losses on the part of the owner for late project delivery and reduced morale of the workforce (Abdelhamid & Everett 2000). In fact, as elaborated by Rubio, Menéndez, Rubio, and Martínez (2005), occupational accidents in the construction industry cause economic and social problems of first magnitude.

The 'root cause' of the accident is unsafe behaviour on the part of a person involved directly in the dynamic flow of events (Rasmussen, 1999). It was reported that 70-80% of the industrial accidents were due to unsafe behaviour. Behaviours have always had a role in occupational safety. For instance, French and Geller (2012) recommended that, when designing and evaluating safety processes, attention needs to be in three basic domains; namely, environment, person, and behaviour. Behaviours are regarded the primary, and sometimes only, tools for survival, remaining today as the last tool when all else fails (Galloway, 2012). Galloway (2012) further explained that when proper tools or systems were lacking, workers should behave in a manner for self-preservation. Thus, promoting safe behaviour at work is a critical part of the occupational safety.

Good safety behaviour, together with management systems and operational procedures can minimise unsafe acts, and reduce the potential for accidents (Institution of Occupational Safety and Health [IOSH], 2014). As a result, Behaviour Based Safety (BBS) has emerged creating a new era of research (Geller, 2005). BBS refers to the use of applied behaviour analysis methods to achieve continuous improvement in safety performance (Krause, 1997). Furthermore, BBS is defined as a systematic approach to promoting behaviours supportive of safety assurance (Sulzer-Azaroff & Austin, 2000). A number of comprehensive literature reviews provide objective evidence for the effectiveness of BBS to enhance safety (McAfee & Winn, 1989; Petersen, 1989; Sulzer-Azaroff & Austin, 2000; Sulzer-Azaroff, McCann, & Harris, 2001). Although BBS systems may vary in form and complexity, at the most basic level, all successful BBS programs share several common elements (Sulzer-Azaroff & Austin, 2000).

These four steps are identifying behaviour that impact occupational safety, looking for factors to understand and improve behaviour, developing and implementing interventions to improve their current status and, evaluating the results to reinforce progress (Daniels, 2010; Geller, 2005; Sulzer-Azaroff & Austin, 2000). The basic steps in the BBS are illustrated in Figure 1-1.

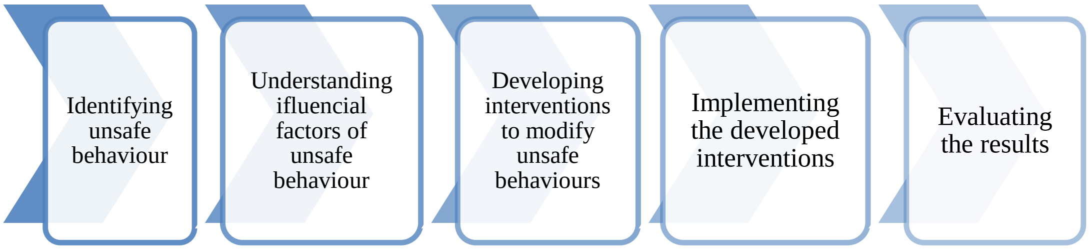

Figure 1-1: Steps of BBS

Source: (Adapted from Daniels, 2010; Geller, 2005; Sulzer-Azaroff & Austin, 2000)

1.2 Research problem statement

Construction safety has often been researched, and they regard the construction industry as the most hazardous industry worldwide, as well as in Sri Lanka (HSE, 2016; Jannadi & Bu-Khamsin, 2002; N. De Silva & Wimalaratne, 2012; Rameezdeen et al., 2003). The extent of construction accidents in Sri Lankan context is more severe compared to other industries (Priyadarshani et al., 2013; Rameezdeen et al., 2003). Thus, it is in a great need to improve construction safety (Ho, Ahmed, Kwan, & Ming, 2000; Kines et al., 2010; Priyadarshani et al., 2013). Along with poor safety performance in the construction industry, BBS is highlighted as an important aspect to ensure occupational safety.

As mentioned in Section 1.1, the importance of BBS and how it can help control and minimise the construction accidents and increase efficiency of their ongoing operations in the long run are been recognised (Choudhry, 2012; Jasiulewicz-Kaczmarek, Szwedzka, & Szczuka, 2015). Despite the recognition, use BBS approaches to enhance safe behaviour of construction workers are yet to be studied in a systematic way. This may be due the lack of studies to identify unsafe behaviour of construction workers and their influential factors in a detailed manner, which are the first two steps in BBS to implement successful interventions to promote safety among workers (Choudhry, 2014; McDonald & Hrymak, 2002). By identifying these unsafe acts and influential factors of workers' unsafe behaviour; better control of the behaviour of workers at site level can be anticipated to enhance occupational safety (Choudhry, 2014; IOSH, 2014; Jasiulewicz-Kaczmarek, 2015).

Thus, the research focused to identify the acts those characterise the unsafe behaviour and factors those influence them to be utilised in developing a predictive model of unsafe behaviour, which can serve as a tool to support the third step in BBS; development of interventions to reduce unsafe behaviour.

The fundamental research questions arisen from the above discussion, which needed answering in order to bridge the knowledge gaps, are;

RQ1. What are the acts those characterise the unsafe behaviour of construction workers?

RQ2. What are the factors those influence the unsafe behaviour of construction workers?

RQ3. What is the impact of these influential factors on construction workers' unsafe behaviour?

1.3 Research aim and objectives

Aim

To develop a model to predict the unsafe behaviour of construction workers in Sri Lanka

Objectives

i.) To identify the acts those characterise the unsafe behaviour of construction workers in Sri Lanka

ii.) To identify the factors influencing unsafe behaviour of construction workers in Sri Lanka

iii.) To develop a model to predict unsafe behaviour of construction workers in Sri Lanka

1.4 Research design

The research was carried out in four phases. In the first phase, a background study was conducted to identify the research problem and to establish the aim and the objectives of the study. Further, the scope and limitations were also defined accordingly. Second phase was to carry out a comprehensive literature review to gather knowledge around the research problem and gain in-depth understanding of the research area. The acts those characterise the unsafe behaviour of construction workers and the factors influencing unsafe behaviour were identified and draft questionnaire was designed in this phase. A pilot study to refine the literature findings was also conducted. Substantive experts from the industry and relevant authorities were interviewed in order to get the literature findings validated to Sri Lankan context. A test run of the questionnaire was carried out to identify any difficulty that can be encountered during the main questionnaire survey. First two objectives of the research were achieved in the completion of this phase.

Once the questionnaire was finalised, it was distributed among construction workers in C1 building construction organisations in Colombo, Sri Lanka, in order to collect data, which was the third phase of the study. The fourth and the final phase was data analysis and conclusions drawing. The data collected through the survey was analysed using Statistical Package for the Social Sciences (SPSS) Version 20 and Neuroph Studio 2.6 software packages to assess the reliability of the scales used and to develop the Artificial Neural Network (ANN) model to predict the unsafe behaviour of construction workers respectively. A sensitivity analysis of the developed ANN predictive model was carried out to demonstrate the underlying relationship between dependant and independent variables used. Further, the developed model was validated for genaralisability using 7 new data points. Conclusions were drawn out as to complete this final phase of the study. Figure 1-2 depicts the entire research process.

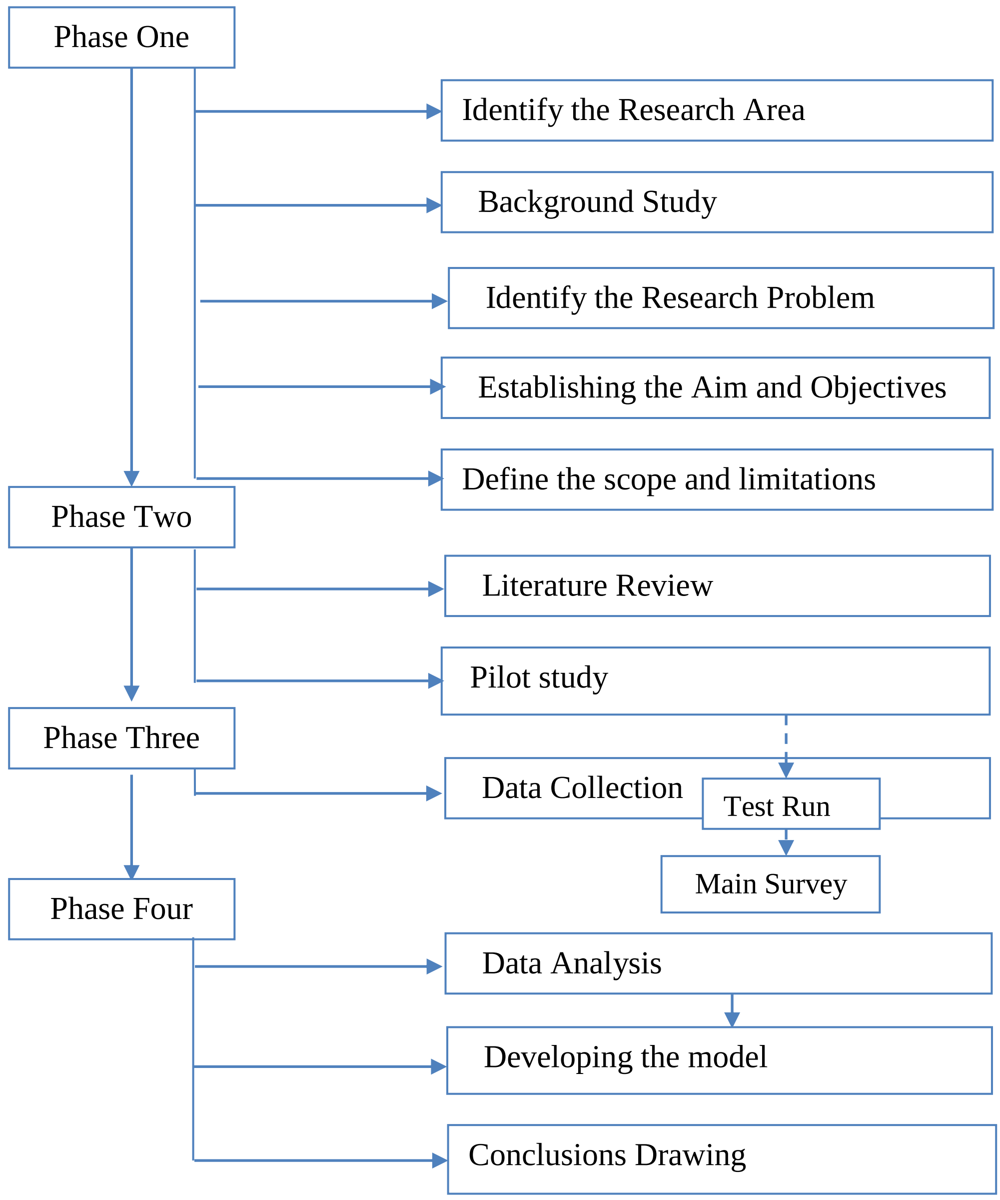

Figure 1-2: Research work plan

1.5 Scope and limitations

The scope of this research was limited to study the unsafe behaviour of construction trade workers in Sri Lanka. Foreign labourers were excluded from this study and the C1 building construction companies in Colombo District, Sri Lanka was considered in the research taking in to consideration the scope of construction projects undertaken by different grades of companies and the time constraint.

1.6 Chapter breakdown

The thesis consists of five chapters, covering introduction to the research, literature review, research methodology adopted, data analysis and findings of the study and conclusions, as illustrated in Figure 1-3.

CHAPTER 1 : Introduction

- Background & research problem
- Aim, objectives, research design
- The scope and limitations

CHAPTER 2 : Literature Review

- Occupational safety in the construction industry
- Causes of occupational accidents
- Unsafe behaviour in construction, and factors influencing unsafe behaviour of workers

CHAPTER 3 : Research Methodology

- The research methodology of the research
- The adopted research paradigm, strategy, and method

CHAPTER 4 : Data Analysis and Findings

- The research findings
- Develop a model to predict unsafe behaviour of construction workers
- Discussion on how influential factors relate to unsafe behaviour of workers

CHAPTER 5 : Conclusions

- Summary of key findings
- Practical implications of the research
- Address limitations and opportunities available for further research

Figure 1-3: Chapter breakdown

1.7 Summary

This chapter intended to provide an introduction to the overall research. Firstly, the background information of the research were presented. The background study exposed constructions industry to be one of the most accident prone industries worldwide as well as in Sri Lanka. The most prominent course of construction accidents was revealed to be the unsafe behaviour of construction workers. Hence, the necessity of carrying out the study to identify unsafe behaviour and its influential factors was justified leading to the research problem statement.

Then, the chapter defined the aim as to develop a model to predict unsafe behaviour of construction workers in Sri Lanka. Three objectives formulated accordingly were also presented. The method used to achieve the formulated objectives and the ultimate aim of the research was discussed in the subsequent section. Moreover, in the latter sections of the chapter, the scope and limitations of the research were emphasised, and the chapter breakdown of the thesis was presented. The next chapter details the literature review of the study.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

Research background, problem, aim and objectives were detailed in Chapter 1. The purpose of this chapter is to discuss the research problem in detail presenting the essential findings of the literature review in a systematic manner. Firstly, Section 2.2 provides an introduction to occupational safety in the construction industry which is followed by the causes of construction accidents under Section 2.3. The chapter moves on to discuss the BBS in Section 2.4. Subsequently, human behaviour, unsafe acts of construction workers and the influential factors of unsafe behaviour are elaborated in Section 2.5, Section 2.6 and Section 2.7 respectively. The predictive modelling methods are presented under Section 2.8, leading to Section 2.9 which discusses the suitable method for modelling unsafe behaviour of construction workers. The chapter is concluded with an overview of the selected method in Section 2.10.

2.2 Occupational safety & accidents in construction industry

A construction site is a place accustomed to work accidents (Gherardi, Nicolini, & Odella, 1998). The construction industry is a large conglomeration of industries and sectors which add value to the creation and maintenance of fixed assets within the built environment (Rameezdeen, 2006). Though it contributes values, the unfortunate situation is that its high rate of occupational accidents (Rameezdeen et al., 2003). The study by Rubio et al. (2005) has emphasised that occupational accidents that take place in construction constitute an economic and social problem of the first magnitude. Every accident led to tragedies such as injury or death to persons, damage to property and the environment and associated direct and indirect costs and effort (Ahmad, Balaban, Doll, & Dreyfus, 2013). Further, there can be financial losses due to delays in the construction process. The delays and total expenses following an accident are usually much higher than the original cost of establishing and maintaining safety standards (Stewart, 2005).

There are specific characteristics of construction sector which have influenced that safety requirements should be applied throughout the process of construction work. A study by Hinze (1997) has discussed that characteristics of the industry such as dynamic work environments, the use of heavy equipment and seemingly unavoidable worker hazard interactions contribute to disproportionate injury and illness rates compared to other work industries. Furthermore, construction work often relates to high risk activities such as, working at heights, demolition, removal or disturbance of asbestos, work at trenches or shafts, temporary supports for structural alterations, powered mobile plant, explosives, confined spaces, work that is in, on or near: electrical installations or services, contaminated or flammable atmospheres ("WorkSafe", 2013). Thus, when occupational accidents are discussed, the construction industry is regarded as the third most likely industry causing work-related injury, after mining and agriculture (Lim, 2007). Although it is difficult to quantify the labour accidents on a world scale, an estimated 350,000 workers die every year in labour accidents (Rubio et al., 2005). Of these accidents, 60,000 occur in the construction industry. That is, a construction worker dies every 10 minutes somewhere in the world, labelling the industry as one of the most hazardous and accident-prone industries worldwide. This fact is often proven by the statistics relating to construction accidents.

According to statistics, in 2003-2004, there were 3,760 major injuries in construction in the UK (HSE, 2005). More alarmingly, during 2004-2005, there were 69 construction fatalities in the UK, representing one-third of all worker deaths in that period (HSE, 2006). This figure has been increasing lately. Only in 2011-2012, there was a reported total of 1.4 million lost working days: 818 thousand due to ill health and 584 thousand due to workplace injury in the UK construction industry (HSE, 2013). Moreover, in the USA construction sector, there were 817 recorded fatalities in 2012 (BLS, 2013). The average fatal accident frequency rate in the Indian construction industry is 15.8 for 1000 employees ("Webindia123", 2014). Moreover, according to Labour department of the government of the Hong Kong special administrative region (2014), the number of reported construction accidents in Hong Kong, in the year 2013, was 3332 with 37 fatalities. When the Malaysian construction sector is discussed, department of occupational safety and health (2014) has recorded 69 deaths, 83 non-permanent disabilities, and 12 permanent disabilities in the year 2013.

Though the construction output is less in Sri Lanka, the magnitude of the accident rate in the construction industry is still significantly high (N. De Silva & Wimalaratne, 2012). The annual accidents in the construction sites were 750-900, and among them, 50-60 were fatal (Amarasinghe, 2010). Furthermore, this annual figure represented more than 30% of accidents which was about 13 times higher than in the other industries in Sri Lanka (Amarasinghe, 2009; Rameezdeen et al., 2003). Thereby, Sri Lankan construction industry is in a proven need to adhere to safety more than any other industry with unacceptable accident rates. Thus, thorough understanding of the accident generation mechanism is necessary for accident preventions (Shin, Lee, Park, Moon, & Han, 2014). Hence, the next section discusses the causes of construction accidents.

2.3 Causes of construction accidents

Occupational accidents are defined as unplanned occurrences which result in injuries, fatalities, loss of production or damage to property and assets (Raouf, 2011). They are the result of unsafe behaviours (human error) and unsafe conditions, or a combination of both (Al-Hemoud & Al-Asfoor, 2006; Heinrich, 1931; Magyar Jr., 2006). Unsafe behaviour is an element immediately before an accident which is significant in initiating the event, such as risk taking, shortcuts, carelessness, lack of attention and horseplay. Whereas the unsafe condition is a poor physical condition existing in the workplace environment immediately before an accident event which is significant in initiating the event (“SafetyPortal”, 2013).

The construction industry has managed safety mainly through focusing on improving the 'hard' issues such as managerial systems, policies and better safety technology (e.g., nets, harnesses), in other words, unsafe conditions (Shin et al., 2014). However, in recent times, many organisations have realised that their accident rates have 'levelled off' (Oswald, Sherratt, & Smith, 2013). The authors further revealed that this has ignited a search for improvements in other areas to reduce accident numbers and has led to the research into behavioural safety issues of the workforce (Oswald et al., 2013). Thus, more recently, researchers are debating that a majority of workplace accidents and injuries are attributed to the unsafe behaviours of employees rather than unsafe working conditions (Mullen, 2004). In a study examining contributory factors associated with 100 construction accidents (Haslam et al., 2005), 70% of accidents were estimated to have involved failure associated with human error (e.g., behaviour and capability). These failures included workers' disregard for safety over other project priorities, inadequate hazard awareness and appraisal and workers' propensity toward least efforts to accomplish defined project goals.

Unsafe behaviours have previously been researched in detail. Accident causation was pioneered by Heinrich (1936) with his development of the domino theory. The Domino theory asserts that 88% of all accidents are caused by unsafe acts of people, 10% by unsafe actions, and 2% by acts of God (Raouf, 2011). Heinrich (1936) proposed a "five-factor accident sequence" in which each factor would actuate the next step in the manner of toppling dominoes lined up in a row. The sequence of accident factors is given by Figure 2-1.

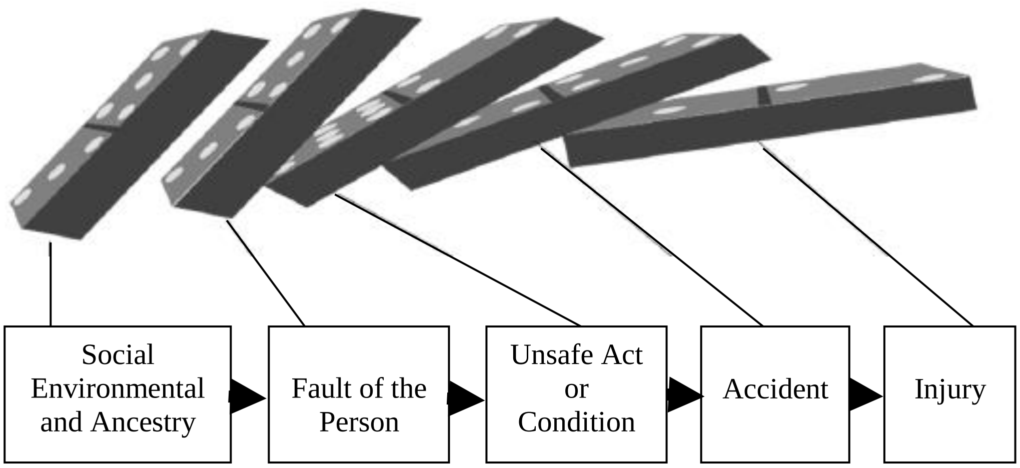

Figure 2-1: An illustration of the domino theory

Source: (Heinrich, 1936)

In the same way that the removal of a single domino in the row would interrupt the sequence of toppling, Heinrich (1936) suggested that removal of one of the factors would prevent the accident and resultant injury, with the key domino to be removed from the sequence being the third domino. Following the seminal work by Heinrich (1936), there have been further considerable efforts towards investigating how accidents occur. Another accident ratio that is often referred to is the 80:20 ratio (80% unsafe behaviours, 20% unsafe conditions) by Al-Hemoud and Al-Asfoor (2006). The authors explain that, if human factor aspects such as equipment/process design and work procedures that have an influence on the unsafe conditions are also considered, then the accident ratio would be changed to 96:4. This ratio considers that the human unsafe behaviour element is, even more contributing to accidents. This theory was further supported by Manu (2012) who reviewed accident and their causes within construction industry (refer Table 2-1).

Table 2-1: Construction accident causation studies

Author	**Location of study**	**Method of study**	**Causes of accident /findings**
Hinze (1996)	USA	Desk study	Accidents are caused by worker distraction either due to physical hazards or mental diversion.
Lam and Rowlinson (1997)	Hong Kong	Analysis of government statistics.	The causes of accident are employment of unskilled workers, overtime work, lack of leadership from top management, poor working attitudes, shortage of factory inspectors, low penalties for breaches of the safety law, inadequate safety education courses, inadequate authority of the Labour Department, and poor site supervision.
Abdelhamid and Everett (2000)	USA	Desk study	Three root causes of accidents: (1) failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started; (2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and (3) deciding to act unsafely regardless of initial conditions of the work environment.

Author	Location of study	Method of study	Causes of accident /findings
Lubega, Kiggundu, and Tindiwensi (2000)	Uganda	A case study involving interviews, and a questionnaire survey	Causes of accidents include lack of awareness of safety regulations; lack of enforcement of safety regulations; poor regard for safety by people involved in construction projects; engaging incompetent personnel; non-vibrant professionalism; mechanical failure of construction machinery/equipment; physical and emotional stress; and chemical impairment.
Toole (2002)	USA	Desk study	Primary causes of accidents be a lack of proper training; deficient enforcement of safety by supervisors; safety equipment not provided; unsafe methods or sequencing; unsafe site conditions; not using provided safety equipment; poor attitude towards safety; and isolated, sudden deviation from prescribed behaviour.
Hinze, Huang, and Terry, (2005)	USA	Examination of 743 ‘struck by’ accident cases	Causes of accidents include misjudgement of a hazardous situation; malfunction of procedure for securing operation or warning of hazardous situation; and inappropriate procedure for handling materials for the task.
Chi, Chang, and Ting (2005)	Taiwan	Examination of 621 occupational fatal accidents	Causes of accidents include lack of complying scaffold/platform; unguarded openings; and lack of fixed barrier.
Choudhry and Fang (2008)	Hong Kong	Interviews with seven operatives, two site engineers, two safety managers and one project manager	Accident causes are inadequate supervision, inadequate training, inadequate planning, employee error, and accident beyond one's control.
Hamid, Majid, and Singh (2008)	Malaysia	Analysis of 128 accident cases and a questionnaire survey.	Causes of accidents are unsafe equipment, job site conditions, unique nature of the industry (e.g., work at height, transient workforce, the high energy required, limitation of working area), unsafe method, human element (e.g. negligence), and management (e.g. poor inspection).
Ling, Liu, & Woo (2009)	Singapore	Examination of 40 fatal construction accidents	Causes of accidents are rushing to complete work, working without using personal protective equipment, lack of safety awareness, personal negligence, carelessness, and lack of supervision.

Source: (Manu, 2012)

According to the findings of the literature, most of the accidents were caused by direct or indirect unsafe behaviour of the workers. Figure 2-2 illustrates an overall representation of causes of construction accidents at a site.

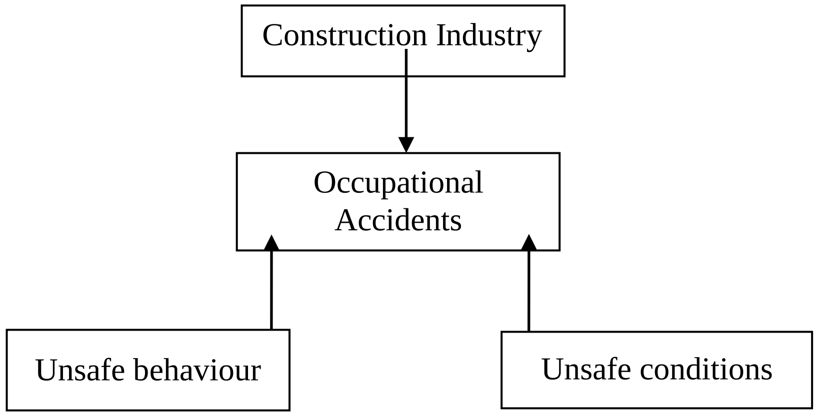

Figure 2-2: Contributing causes to construction accidents

The literature findings imply that accidents can happen due to either an ‘act’ of unsafe behaviour or lack of ‘action’ to eliminate unsafe conditions (Shin et al., 2014). This supports the importance of a behaviour bases safety management approach to construction accident prevention. The next section details the concept and its application.

2.4 Behaviour based safety

It is hard to pinpoint precisely the beginning of the field of BBS as it is known today. However, there was a flurry of work starting in the 1970s. Dr Beth Sulzer-Azaroff, a pioneer in the field of BBS, published the first of many articles on BBS in the journal of organizational behaviour management in 1980 elaborating behavioural ecology and accident prevention. Subsequently, many others have contributed substantially to the evolution of the practice. For example, McSween (1995), a behaviour analyst, who authored ‘The values-based safety process: Improving your safety culture with a behavioural approach’, and Geller (2001), who wrote ‘Working safe: How to help people actively care for health and safety’, have had a significant impact on the field in the past two decades. Further, Krause (1997) used BBS approach to achieve continuous improvement in safety performance. Thus, the emphasis of the BBS to safety is, as the name suggests, on employees' observable and measurable behaviour critical to safety in a particular setting. BBS is a task-oriented view of behaviour, and it treats safe behaviour as a critical work-related skill (IOSH, 2014). As mentioned in Section 1.1, at the most basic level, BBS is tiered-up with identifying the unsafe behaviours (or target behaviours that may impact safety), understanding underlying causes of the unsafe behaviour, developing and implementing interventions to increase behaviour supportive of safety and evaluating the results.

Hence, BBS is defined as a systematic approach to promoting behaviour supportive of injury prevention and use to control, manage and assess the unsafe behaviour of employees (Sulzer-Azaroff & Austin, 2000). However, depending on the context, the BBS approaches may vary in form and complexity.

As discussed in Section 1.1, identification of unsafe behaviour in a particular context and understanding its underlying causes/influential factors are the primary steps of any BBS approach to safety management. Effective interventions to control the unsafe behaviour of workers can only be developed by understanding those unsafe behaviours and their influential factors. The succeeding sections discuss the concept of behaviour and the unsafe behaviour of construction workers in details.

2.5 Human behaviour

Human behaviour is discussed in various perspectives like anthropology, psychology, personality science and so on throughout the literature (Cronk, 1991; Davies, Krebs, & West, 2012; Grafen 2006; Winterhalder & Smith, 2000). According to research, 'behaviour' varies from phenomena such as one's degree of talkativeness during social encounters (Furr & Funder, 1998), to academic performance as reflected in one's score on a statistics test (Hair & Hampson, 2006), to 'behavioural impulsivity' as reflected in participants' performance on computerized attention tasks.

Aunger and Curtis (2008), in a much definitive description, defined behaviour as self-propelled movement producing a functional interaction between a being and its environment. These interaction either can be psychological or physical. For instance, a recent study of attachment in romantic relationships used observational data to reveal the display of ‘emotional, instrumental, and physical caregiving behaviour’ in stressful situations (J. A. Simpson, Winterheld, Rholes, & Oriña, 2007). Furr (2009) explained that such data should be distinguished from behaviourally derived data reflecting other psychological responses, because those are most clearly interpretable as indicators of cognitive events. Almost all data might be deemed ‘behavioural’ in this second sense (Furr, 2009). Thus, the research focused on behaviour in the first sense intended to represent how a person acts rather than how a person thinks, feels or otherwise responds.

When such behaviours are concerned, research assert that humans are remarkable for their ability to adapt to new niches much faster than the time required for genetic change (Laland & Brown 2006; Nettle 2009; Wells & Stock 2007). A study conducted by Furr (2009) classified behaviour into two categories as contextual and general. The researcher defined globally retrospective behaviour as general and contextually retrospective behaviour as contextual. Numerous research have dealt with this contextual variable under different headings: ‘third variable (Skinner, 1931), ‘setting factor (Kantor, 1946), ‘setting event’ (Bijou & Baer, 1978; Bijou, 1996), and ‘contextual determinant’ (Pelaez-Nogueras & Gewirtz, 1997).

This research was limited to a particular context and area of performance. Further, the aim of the study was to predict the level of unsafe behaviour of a worker, which is contextual to construction industry. Hence, this research focused on data representing an individual’s behaviour in that particular context. Hence, observable unsafe behaviour of construction workers in the contexts of construction and occupational safety was taken into consideration.

2.6 Unsafe behaviour of construction workers

There is no general agreement on the definition of unsafe behaviour. However, it has been defined in focus on unaccepted practices which have the potential for producing future accidents and injuries. For example, Stranks (1994) defined the unsafe behaviour as any act that deviates from the recognised safe way of doing a job and increases the likelihood of an accident. Furthermore, an unsafe behaviour is defined as an act that is committed without considering safety rules, regulation, standards and specified criteria in the system, which can affect the system safety level (Fuller, 2005).

For instance, conduct at the workplace, which deviates from accepted safety norms, can be unsafe for the worker as well as the other employees on site. Furthermore, ergonomically wrong movements such as working at improper speeds, exceeding the prescribed speed limits and improper posture for tasks, make the worker unsafe, for they can cause musculoskeletal disorders (Da Costa & Vieira, 2010). Aksorn and Hadikusumo (2007) explained that servicing equipment which is in operation, for instance, refuelling a machine without first turning off the engine could cause a severe accident. Also, not wearing PPE may increase chances of getting injured and lack of use of PPE has become a critical concern in workplaces (Cavazza & Serpe, 2009).

A number of acts of unsafe behaviour have been identified by many researchers such as Abdelhamid and Everett (2000), Anton (1989), Holt (2001), Michuad (1995), Petersen (1984), Stranks (1994), and Simachokdee (1994). These researchers identified various acts of unsafe behaviour those could lead to serious accidents or fatality, under interchangeably used terms and phrases. By reviewing the available literature, 15 distinctive unsafe acts those have the potential to cause occupational accidents on site were identified. Figure 2-3 denotes the identified acts of the unsafe behaviour of construction workers.

Construction Industry

Unsafe Behaviour

Unsafe Acts

Working without authority on the job

Annoyance and horseplay in the workplace

Smoking, creating naked flame or sparks in areas where flammable materials are stored

Leaving nails or other sharp objects protruding from surfaces

Throwing or dropping objects from high levels

Working under the effects of alcohol/drugs

Working with lack of concentration

Working in poor physical conditions

Working at improper speeds

Improper posture for tasks

Incorrect use of tools and equipment

Using defective equipment and tools

Not wearing PPE

Removing safety guards from the workplace or equipment

Servicing equipment which is in operation

Figure 2-3: Unsafe acts of construction workers

2.7 Factors influencing unsafe behaviour of construction workers

It is important to identify factors that influence unsafe behaviour and to control them when behavioural change is needed (Geller, 2005). There were many studies with substantive focus on identifying factors that influence the unsafe behaviour and accidents, studies in which the participants were construction employees and unsafe behaviour and accidents were work-related in the literature (Almen, Bringeland, Fredriksson, & Schiöth, 2012; Choudhry, Fang, & Lingard, 2009; Fang, Chen, & Wong, 2006; Fleming & Lardner, 1999; Gibb, Lingard, Behm, & Cooke, 2014; Hamid, Yusuf, & Singh, 2003; Hinze, 1997; Ismail & Ab-Ghani, 2012; Pungvongsanuraks, Thitipoomdacha, Teyateeti, & Chinda, 2010; Siu et al., 2003; Vitharana, De Silva, & De Silva, 2015). When reviewing the available literature, it was identified that the influential factors of unsafe behaviour can be mainly categorised into three main constitutes as Person (Individual Dynamics), Process (Work Environment) and Place (Organisational Safety Culture) (refer Figure 2-4).

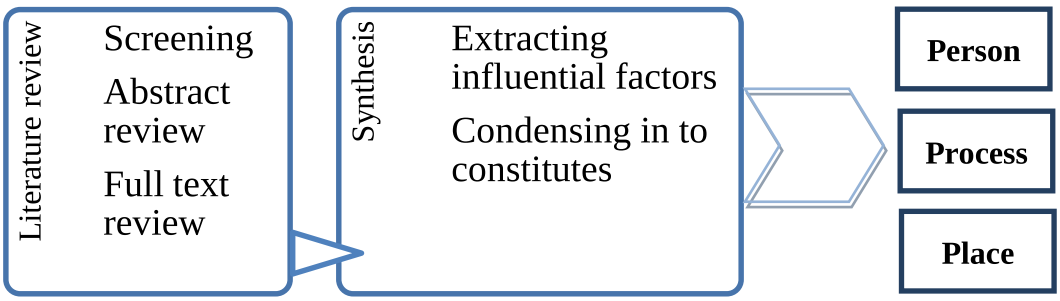

Figure 2-4: Literature review briefing

2.7.1. Person (Individual dynamics)

Personal factors influencing unsafe behaviour have been addressed since the 1930s, with the work of Heinrich (1931) on industrial accidents prevention. Quality rating of previous studies showed that one of the most important factors influencing unsafe behaviours and accidents was individual dynamics. Thus, many studies have been conducted aiming to identify those factors (Choudhry et al., 2009; Fang et al., 2006; Fleming & Lardner, 1999; Gibb et al., 2014; Hinze, 1997; Siu et al., 2003). Fleming and Lardner (1999) have discovered the personal factors contribute to 80 – 90% of all industrial accidents. According to Hinze (1997), substantial influence had been determined for demographic factors as age, gender, education level and working experience. Siu et al. (2003) investigated age difference in safety attitudes and safety performance in Hong Kong construction workers with data from 374 Chinese construction workers from 27 construction sites. The study found that the older workers exhibited more positive attitudes toward safety.

Fang et al. (2006) used logistic regression to explore the relationship between safety climate and personal characteristics. Personal characteristics including age, gender, education level, alcohol/drug abuse, were found to be related to safety behaviour of workers. Choudhry et al. (2009) found positive effects upon safety perceptions of older workers, who are married and have more family members to support while those who are in the youngest age, single, or have no family member to support demonstrated adverse effects. Workers with educational levels below primary had less perception of the safety climate.

By reviewing the available literature, a number of factors were identified under the ‘person’ constitute, including ‘Age’ (Carpenter, Lee, Gunderson, & Stueland, 2002; Choudhry et al., 2009; Hinze, 1997; Parker et al., 2007; Sawacha, Naoum, & Fong, 1999; Seixas, Blecker, Camp, & Neitzel, 2008), ‘Educational Level’ (Hinze, 1997; Carpenter et al., 2002; Parker et al., 2007; Seixas et al., 2008; Masood & Choudhry, 2012), ‘Experience’ (Siu, et al 2003; Choudhry & Fang, 2008; Masood & Choudhry, 2012), ‘Gender’ (Carpenter et al., 2002; Fang, Chen, & Wong, 2006; Masood & Choudhry, 2012), ‘Alcohol/drug abuse’(Fang et al., 2006; Masood & Choudhry, 2012), Psychological distress (Abbe, Harvey, Ikuma, & Aghazadeh, 2011; Borys, 2012; Lai, Liu, & Ling, 2011; López, Ritzel, Fontaneda, & Alcantara, 2008), income (Choudhry & Fang, 2008; Fang, Xie, Huang, & Li, 2004; Hinze & Teizer, 2011; Suraji, Duff, & Peckitt, 2001; Zheng, Xiang, Song, & Wang, 2010) and attitudes towards safety (Cox, 1990; Cox & Cox, 1991; Dester & Blockley, 1995; Zohar, 1980).

Age – By regulation, the a worker is permitted to work if he/she is above 18 years of age, and required to retire on completion of 55 years (for males)/50 years (for females) (Central Bank of Sri Lanka, 2017; Department of Labour, 2017). Research has suggested that the engagement in unsafe acts of the worker varies with the age. For instance, a study by Mousavipour, Variani, and Mirzaei (2016) found a significant inverse relationship between unsafe acts and age of workers. Siu et al (2003) found that the older workers exhibited more positive attitudes toward safety. Thus, young workers are more prone to accidents than old workers. Young people are energetic and often reckless. As they age, the physical agility and daringness of workers tame, and they tend to behave more safely for their protection. However, in a study on workers unsafe behaviours using safety sampling method (Abbasi, Gholamnia, Alizadeh, & Rasoulzadeh, 2015) the maximum and minimum frequencies of unsafe observations were reported to be from age groups older than 51 years old and 26-30 years old respectively. Furthermore, in a study conducted by Q. Yin (2016), it was revealed that aging has mildly negative effects on safety performance of the workers, as in general older workers entered danger zones more frequently.

Gender – In a study about safety climate and construction industry, Fang et al. (2006) found statistically significant relationship among gender and individual unsafe behaviour. Men only have around 1.5 times higher accident rate than women in agriculture. Men’s accident rate is 2.33 and 3.33 times higher than women’s rate in manufacturing and construction respectively (European Agency for Safety and Health at work [EU-OSHA], 2013).

However, the construction industry is typically a male dominated industry and presents a major challenge for equal opportunities for women (Amaratunga, Haigh, Lee, Shanmugam, & Elvitigala, 2006) due to the factors militating against the participation of women in the construction work place, such as heavy work, recruitment to the industry, gender discrimination, and social norms (Agapiou, 2002; Bennett, Davidson, & Galeand, 1999). Thus, accident rate of women is recorded low due less representativeness. However in Sri Lanka, rate of women engaged in construction industry is lowest compared with other industries such as agriculture and services (Department of Census & Statistics, 2016).

Experience - Laukkanen, (1999) reported the experienced and skilled construction workers to being less prone to hazards than inexperienced workers, while human experiences influence safe or unsafe actions on-site and involvement in safety management systems (Fang et al., 2004; Gibb et al., 2014). Supporting this, Stokdyk (1994) found that more than half of all accidents on site occur within the victim's first week. Similarly, more experienced workers in the industry are less likely to be behaving unsafe manner while they work (Choudhry & Fang, 2008; Masood & Choudhry, 2012; Gibb et al., 2014; Siu et al., 2003). This is because experience let the workers know what sort of danger they are dealing with and what would the consequences be of work-related accidents in construction (Abbasi, Gholamnia, Alizadeh, & Rasoulzadeh, 2015). Thus, workers with more years of experience in the industry would naturally accustomed to safe behaviours than those with less experience.

Construction is a labour intensive industry that places heavy reliance upon the skills of its workforce (Agapiou, Price, & McCaffer, 1995). Paucity of experienced workforce results poor quality, high wastage and long-term productivity decline in the industry (Jayawardane, & Gunawardena, 1998). According to Dainty, Ison, and Briscoe (2005), insufficiency of experienced and skilled workforce in the industry can generate poor work quality and delays in completion times of the projects and it leads general contracting firms to restrict their ambitions for growth, despite the buoyant nature of the construction industry.

Alcohol/Drug abuse **-** It has been estimated that 20–25% of workplace accidents are alcohol/drug related (Henderson, Hutcheson, & Davies, 1996). Among the major occupational categories, workers in the construction industries exhibit some of the highest rates of substance abuse, with rate of current illicit drug use estimated to hover around 14.1% (Laad, Adsul, Chaturvedi, & Shaikh, 2013). Biggs and Williamson (2012), in their study of nearly 500 construction workers in Australia, deemed 286 (58%) were above the cut-off score for hazardous alcoholic consumption. They further asserted that, although it is not clear to what extend the drinking out of work hours will affect safety during construction, it would be naïve to think that none of the workers would be impaired. Drug takers of such highs are high-risk takers that live for the "buzz" (sensation seeking). They are aware of the risks (e.g., heart attacks and addiction), but the "buzz" feeling still outweighs the consequential thinking (Oswald et al., 2013).

As Frone (1999) posits alcohol abuse and dependence especially undermine the level of productivity as well as the general health and wellbeing of workers. Other researchers (Ames, Grube, & Moore, 1997; Frone, 1998) have found the effects alcohol have on work which include:

- Inability to perform tasks as expected
- Injuries and accidents at the workplace
- Absenteeism ,poor attendance and possible turnover

These problems not only affect performance but could have cost implications for organizations ranging from lost man-hours to payment for healthcare as a result of injuries at the workplace and especially so at the construction site in the context of the construction industry (Duodu, Koh, & Rowlinson, 2014).

Education - Knowledge encompasses all that a person knows or believes to be true, whether or not it is verified as true in an objective or external method. It is the individual's personal stock of information, skills, experiences, beliefs and memories (Alexander et al., 1991; Gibb et al., 2014; Reber & Reber 2001). Knowledge is always idiosyncratic as it reflects the vagaries of a person's history (Alexander et al., 1991). Education, as a knowledge acquisition mean, does have a positive impact on safety behaviour of workers (Hinze, 1997). His research suggests that it is easier to maintain safety standards when the workforce consists of individuals with a sound educational background. Individuals with good education understand the importance of following safety guidelines in work and compile with safety practices than those with an education level of primary or lower.

In Sri Lanka, this has been addressed with the introduction of safety and health into G.C.E. advanced level and ordinary level syllabuses. Further, recently, CIDA has commenced two programmes for safety officers and managers.

Attitudes towards safety - Attitudes are learned tendencies to act in a consistent way towards something or someone (Bluff, 2011). Those are settled ways of thinking or feeling which reflect an individual's disposition to a person, situation or thing, and may reflect underlying values (Ajzen & Fishbein 1980; Aronson, Wilson, & Akert, 1997; Glendon, Clarke, & McKenna, 2006; Reber & Reber, 2001). According to Aronson et al. (1997), attitudes help an individual to adapt to a group, interpret phenomena and behave accordingly. The author further explained that attitudes could provide defence against unpleasant realities which are threatening or anxiety producing. A positive safety culture includes individual attitudes concerned with minimising the exposure of individuals to conditions considered dangerous or injurious (Chinda, 2016; Dester & Blockley, 1995). Confirming this, a study by Langford, Rowlinson, and Sawacha (2000) identified that positive attitudes towards occupational safety lead to safe behavioural patterns displayed by construction workers.

However many developing countries including in Sri Lanka, peoples' attitude towards safety is not positive. This may be due to lack of leadership and management commitment, low profit margins, and lack of knowledge about safety (Mohamed, 2002; Rundmo & Hale, 2003; Sawacha et al., 1999). Strategies such as incentives schemes, rewards for positive attitudes punishments for negativities etc. are suggested by many authors (Brown, Willis, & Prussia, 2000; Leather, 1988; Teo & Wen 2005) in order to enhance the attitudes of the workers towards safety.

Psychological distress – Psychological distress has been characterised by a range of symptoms including lack of enthusiasm, problems with sleep, feeling downhearted or blue, feeling hopeless about the future, and feeling "emotional" for example, crying easily or feeling like crying (Burnette & Mui, 1997; Decker, 1997). Psychological distress differs from organic mental disorders in the sense that it is a reactive disorder affected by external stress (Chinda, 2016; George, Hughes, & Blazer, 1986). Studies of psychological distress in the social sciences typically use the number of depressive symptoms as a measure of distress.

Hofmann and Stetzer (1996) described psychological distress as nonspecific, multiple psychiatric symptoms that can constitute a mental illness severe enough to cause moderate to serious impairment in occupational functioning that is related to employee safety. The results obtained from psychological distress and safety behaviour are inconclusive. Dunbar (1993) reported that safety compliance could be predicted by affect, anxiety, and depression of their work procedures. Oladinrin, Adeniyi, and Udi (2014) stated that there is accumulating evidence that stress levels among construction professionals are on the increase from day to day.

Income- According to Ng, Cheng, and Skitmore (2005), in a market-driven society, it is common for construction stakeholders especially those at the lower end of the supply chain to concentrate exclusively on completing projects to the required quality standard with the minimum time and cost. The researchers suggested that, therefore, safety is regarded as a secondary concern.

Goldenhar, Williams, and Swanson (2003) identified insufficient financial support as an occupational stress. Suraji et al. (2001) verified pressures from the economic conditions as an influential factor in the construction safety. The authors indicated workers could be directly influenced by poor income and economic conditions and as a result, they can be distracted from their work.

Further, workers tend to take risky jobs as it give a "risk allowance" which is a good income source (Ng et al., 2005). However, lack of regulations such as pre-employment testing for specific competencies they should acquire prior to take the job (Piotrowski & Armstrong, 2006), and health screening tests to verify the fitness of workers (Pachman, 2009) can be utilised to minimize the risk faced by those workers when they engage in risky jobs. Thus, it is evident that there is a positive relationship between the income and safe work practices of construction workers.

2.7.2. Process (Work environment)

Most construction activities take place in rapidly changing environments and under evolving site conditions, involving hazardous operation, unsafe conditions, and equipment (Khosravi et al., 2014). In a study by Haslam et al. (2005), 70% of accidents were estimated to have involved failure associated with a human error while other accidents were attributed to workplace constraints, conditions and local hazards, and use of hazardous equipment.

Hazardous equipment and operations coupled with workers' attitudes and behaviours can challenge safety (Choudhry & Fang, 2008). Literature review revealed three main factors particular to the immediate work environment, those influence unsafe behaviour of workers as hazardous operation (Almen et al., 2012; Hamid et al., 2003; Ismail & Ab-Ghani, 2012; Pungvongsanuraks et al., 2010; Vitharana et al., 2015), unsafe conditions (Choudhry & Fang, 2008; Mitropoulos, Abdelhamid, & Howell, 2005; Nouri, Azadeh, & Fam, 2008) and hazardous equipment (Almen et al., 2012; Hamid et al., 2003; Wachter & Yorio, 2014).

Hazardous operations - Pungvongsanuraks et al. (2010) elicited that construction industry is unique and complex compared with other industries and it contains a broad range of operations. These complexities make the construction industry as one of the most hazardous industries that cause a high rate of accidents. Construction often includes hazardous operations such as excavation and trenching, working at heights and use of heavy and mechanised equipment (Pungvongsanuraks et al., 2010). Excavation and trenching have been considered as the most hazardous construction site operation (Vitharana et al., 2015). Scaffolds contribute towards the accident occurrences at the construction workplace (Ismail & Ab-Ghani, 2012). A significant number of construction workers usually get injured in trenching and cave-in accidents every year (Vitharana et al., 2015). Working at heights is also a hazardous operation in construction sites. Falling from high places, like scaffolding, ladder, and roofs, slipping, tripping, and using unstable ladders are some of the common causes of these accidents (Hamid et al., 2003).

Unsafe Conditions – The manual published by International Labour Office in Geneva (1995) indicated that the construction work should be safe, and conditions on the construction site should not cause damage to life, health and professional skills. One of the leading causes of industrial accidents is unsafe conditions and physical hazards, trenches, mechanical explosions, ionising radiation, flammability, corrosion, reactivity, fast moving vehicles, steep grades, unguarded machinery and uneven surfaces (Nouri et al., 2008). Hazard free-construction site is a must to ensure accident-free environment (Choudhry & Fang, 2008; Chinda, 2016).

According to the “systems model of construction accident causation” (Mitropoulos et al., 2005), task characteristics and unpredictability create hazardous situations in the workplace, and the exposure to these hazards creates the potential for accidents. The need of removing unsafe conditions is emphasised in quality standards as well. For example, cleanliness on the site is acknowledged as essential in the specification for buildings published by Architectural Services Department of Hong Kong (2012). It further states that the materials and plant need to be stored neatly, rubbish and debris as they accumulate must be removed and the site must be kept clean and tidy.

It is part of improving the job condition to minimise the risk of accidents in the physical environment. The planned and organised site layout can be helpful to mitigate the risk to construction workers and influence unsafe behaviours in them (Choudhry & Fang, 2008).

Hazardous Equipment - It is relatively easy for safety programs to focus primarily on making changes to or correcting the physical environment, equipment, tools and machinery that may have contributed to the safety incident (Wachter & Yorio, 2014). Physical injury hazards are often caused by equipment used such as power access equipment, ladders, plant and heavy machinery for excavation, piling, lifting, transportation (Chinda, 2016; Hamid et al., 2003). Work equipment can be categorised into four groups as hand tools, lifting equipment and other equipment (ladders, kick stools, water pressure cleaners) according to "Healthy-Working-Lives" (2014). They clarified that each of these equipment has the potential to cause injury. In construction sites, this potential is magnified due to the severity of operation and complexity of process (Almen et al., 2012).

The common cause of equipment accidents are unsafe equipment installation (OSHA, 2002), failure to de-energize electrical systems (e.g. not following lockout/tagout), failure to maintain safe distances, improper use of personal protective equipment (PPE), and poor work practices (e.g., accidentally cutting out live wires with an electric drill or a metal ladder, improper driving manoeuvres or hoisting, and inadequate wiring), accidental contact with live parts (e.g., unguarded switch/conductor, exposed wire, and welding electrode), defective tools and equipment (e.g., defective insulation, damaged cord, soaked with water, ground fault) (Chi, Chang, & Ting, 2005). Improper grounding, and lack of effective safety devices, wet area, confined spaces, and strong wind can also increase the likelihood of an accident when hazardous equipment are been used (Chi, Yang, & Chen, 2009).

2.7.3. Place (Organisational safety culture)

The significance of organisational factors has begun to gain acceptance since the 1970s onwards (Powell, Hale, Martin, & Simon, 1971). Some findings indicate that low-accident companies were eminently better than high-accident companies regarding the management's commitment to safety and in employee training. Meliá and Becerril (2009) demonstrated that factors such as poor supervision, having little guidance for safety, unavailability of rules or procedures, lack of feedback, poor communication, and inadequate managerial support correlate with the unsafe behaviour of workers in an organisational context. Furthermore, it was highlighted in the literature that promoting a positive safety culture is the best way to influence the behavioural safety of the workers. Recent theoretical and empirical studies (Abbe et al., 2011; Glendon & Litherland, 2001; Gibb et al., 2014; Meliá, Mearns, Silva, & Lima, 2008) indicated that safety culture was a multidimensional construct that was often used interchangeably with the term safety climate. Individuals who work in a strong safety culture are likely to adopt safe behaviour than others who are not under the influence of such culture where safety is understood to be and is accepted as the number one priority (Flin, Mearns, O'Connor, & Bryden, 2000).

Moreover, Choudhry, Fang and Mohamed (2007) asserted that management's commitment to safety and concerns for the workforce, mutual trust and credibility between management and employees, workforce empowerment, continuous monitoring, corrective actions, review of system and continual improvements to reflect the safety at the organisation will strengthen the safety culture which will positively affect the behavioural safety of the workers of the organisation.

Pidgeon and O'Leary (2000) identified that a good safety culture could be promoted by four factors: (1) senior management commitment to safety; (2) realistic and flexible customs and practices for handling both well-defined and ill-defined hazards; (3) continuous organisational learning through practices such as feedback systems, monitoring and analysing; and (4) care and concern for hazards which is shared across the workforce. When comparing these factors identified by different authors, it can be observed that they, with slight overlaps among them, do point in the same direction. Management commitment to safety, employee involvement, proper safety procedures and rules, and efficient safety communication strategies can be identified as the most important factors that help to strengthen the safety culture within an organisation and hence enhance the safety behaviour of its employees (Manjula & De Silva, 2013).

Safety procedures & rules - If procedures and rules are well established to capture every safety error and rectify them, employees automatically adhere to these systems (Chinda, 2016; Gibb et al., 2014; Mohamed, 2003; Pidgeon & O'Leary, 2000; Sawacha et al., 1999). Also, monitoring process will give the workers a sense of been watched over and that will influence unsafe behaviours. O'Dea and Flin (2001) showed the 'failure to follow the rules' as the third most significant perceived cause of accidents, after 'not thinking the job through' and 'carelessness'. In a seminal study of safety rules in the Dutch railways by Elling (1991), it was showed that only 3% of workers surveyed used the rules often and almost 50% never used the rules. Moreover, 47% of workers found rules to be not always realistic; 29% thought they were used only to point the finger of blame; 95% believed that, if they kept to the rules, the work could never be completed in time; 79% was under the impression that there were too many rules; 70% expressed that they were too complicated, and 77% thought that the rules were sometimes contradictory. A study by Maidment (1993) showed similar problems in the UK. In a survey by Embrey (1999) of 400 operators and managers in the chemical industry, the reasons respondents gave for not using procedures included, language issues, complexity, time-consuming nature, unawareness of the rules, and inconvenience in using procedures.

Legislation related to safety - The excess of legal rules and procedures surrounding safety, either in the form of procedural requirements or detailed action rules, (Hale & Swuste, 1998; Pink, Morgan, & Dainty, 2014) is seen as further proof of the need to define and document the way in which safety is to be achieved. Occupational Health and Safety Administration Series (OHSAS) is a well-recognised standard which was developed to provide organisations with an internationally accepted system for managing the organisation's activities and processes in order to reduce or eliminate occupational health and safety risks to employees (Beckmerhagen, Berg, Karapetrovic, & Willborn, 2003; Chinda, 2016). Safety and Health in Construction Convention (1988) published by ILO provides detailed technical preventive and protective measures having due regard for the specific requirements of construction sector (Stellman, 1998). The objective of this code is to provide practical guidance on a legal, administrative, technical and educational framework for safety and health in construction with a view to prevent accidents, diseases and harmful effects to workers arising from employment in construction (ILO, 1992). Sri Lankan context is governed by the Factories Ordinance (1942). In accordance with the Factories Ordinance, it is obligatory for the employer to ensure health, safety and welfare of persons at workplace. However, the ILO points out that occupational safety and health laws in Sri Lanka are confined to mines and factories (Samarawickrama, 2013).

Deviance from the procedures and rules of safety is recognised as a primary cause of accidents, castigating to the company and the regulator for not having specific procedures to govern changes (Vaughan, 1997). These studies provide affirmation that rules and procedures are seen as largely desirable, and to define and guide behaviour in complex and often conflicting environments and processes (Hale, Borys, & Else, 2012). Thus, it is clear that having up-to-date, directive, concise procedures and rules for safety is positively related with workers' safety behaviour. Further, it is of vital importance that the workers are aware of them and trained in them.

Management commitment - Management's commitment to safety is generally acknowledged as a fundamental aspect of successful safety performance (O'dea & Flin, 2001; Rundmo & Hale, 2003; Simard & Marchand, 1995). It is critical if an organisation wants to promote safe behaviours among the workers (Choudhry et al., 2007; Chinda, 2016; Donald & Canter, 1993; Rodgers, Hunter, & Rogers, 1993). A committed manager who is personally involved in safety activities and who takes an interest in working conditions conveys to the employees, a sense of the importance of safety in the organisation (Muniz, Ordas, & Peon, 2007; Pink, Morgan, & Dainty, 2014). Management's contribution with the necessary time, resources and positive approach matters for the likely success of an intervention (Gibb et al., 2014; Meyer

& Allen, 1988). Current management practices of safety include but not limited to controlling the workers' safe and healthy behaviour, centralised safety management unit, resources and insurance policies, safety documentation, and safety committee developing safety policies, assigning safety responsibilities to site personnel, developing in-house safety rules, communication between management and worker at site (N. De Silva & Wimalaratne, 2012).

A study by Michael, Evans, Jansen, & Haight (2005) asserted that management's concern for employee well-being through a dedication to safety will result in positive outcomes beyond improved safety performance. The authors further maintained that organizations with a strong commitment to safety may enjoy not only a reduction in safety-related events but also increases in desirable employee attitudes and behaviour.

However, Cooper (1998) revealed that inconsistency between the typical vision statements issued by organisations which state that `safety is a top priority' and actual managerial practices is all too commonplace. According to the author, it is not unknown for safety personnel to try to promote a positive safety culture according to stated company policy, while senior managers are merely concerned with satisfying the minimum of legislative requirements.

Safety communication - Vecchio-Sadus (2007) demonstrated that, in a system of open and two-way communication, management provides employees with relevant information on hazards and risks associated with the organisation's operations to build understanding on how to work safely. People will contribute more efficiently in an environment that provides a framework for consultation and communication that creates the conditions where individuals are encouraged and prepared to report hazards, incidents and near-misses and to reduce those (Chinda, 2016; Shin et al., 2014). Furthermore, Hofmann and Stetzer (1998) showed that safety communication has significantly influenced accident attributions.

Involving employees in decisions about changes and responding to their concerns helps to establish common goals between management and employees, and motivates them to work safely. Cheyne, Cox, Oliver, and Tomás (1998) incorporated communication in safety as one of the components of safety climate. Therefore, communication (an open, free-flowing exchange with management about safety issues within department/company) is of vital importance to the safe behaviour of workers (Pink, Morgan, & Dainty, 2014; Lingard, Pink, Harley, & Edirisinghe, 2015).

Ineffective communication can very likely lead to the stretching of safety margins, and the migration of behaviour towards the boundary of acceptable performance (Rasmussen, 1997). Construction is an industry that largely depends on foreign workforce (N. De Silva, Darmicka, & Fernando, 2014). Different labour cultures and traditions reflect on communication problems due to lack of language competencies, and these can affect the concentration and attention of the worker and may contribute to mistakes (Kartam, Flood, & Koushki, 2000). An alarming number of accidents due to miscommunications on construction sites has been reported in research (Han, Park, Jin, Kim, & Seong, 2008; Lingard et al., 2015; Pink et al., 2014). The challenge of converting the safety systems to accommodate a multinational/ cultural workforce is being addressed using initiatives such as, translation of health and safety materials, use of interpreters and an increased use of visual methods for communicating health and safety messages (Bust, Gibb, & Pink, 2008).

Employee involvement in safety - The best safety management systems involve employees at every level of the organisation. Employees are often those closest to the hazard and must have the most first-hand knowledge of workplace hazards. Thus, they are the best-qualified persons to make suggestions for improvements, of safety (Vredenburgh, 2002). This empowerment of workers provides them with authority, responsibility and accountability for required decisions and ensures that both employees and managements are involved in setting goals and objectives (Chinda, 2016; Townsell, 2011). It induces employees to do their best work as individuals and as a team, while relieving the manager to plan, lead and mentor (Cohen & Cleveland, 1983).

Research has strongly supported the positive relationship of employee involvement in safety with safe work ethics. For instance, in support of employee participation in accident investigation practices, Royal Society for the Prevention of Accidents (RoSPA) (2012) argues that one major pitfall in accident investigation is a lack of workforce involvement. RoSPA also contends that trade union safety representatives have a legal right to participate in accident investigations. Worker involvement has been reported as a decisive factor in safety by Cox and Cheyne (2000), Dedobbeleer and Beland (1991), Lee (1998), Rundmo (1994), and Shannon et al. (1996). Therefore, employees' involvement in safety is considered as a vital safety culture indicator and can positively correlate with employees' safe work practices.

Table 2-2 summarises the findings of the literature review on influential factors of unsafe behaviour.

Table 2-2: Influential factors of construction workers' unsafe behaviour

Factor	**Reference**																																			
Person (Individual dynamics)	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
age								√				√				√	√													√							
gender								√																										√			
experience								√				√				√	√													√							
alcohol/drug abuse																													√		√	√					
education								√																					√								
attitude towards safety			√									√		√						√				√			√	√									
psychological distress	√							√						√				√						√					√								
income									√			√											√			√				√							
Process (Work environment)	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
hazardous operations		√						√																	√		√										
unsafe conditions		√					√			√								√		√					√		√										
hazardous equipment			√	√			√																														

Factor	**Reference**																																				
Place (Organizational safety culture)	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
safety procedures & rules			√		√			√													√	√			√												
management commitment								√	√									√		√	√														√		√
employee involvement											√	√							√				√														
safety communication			√		√	√					√	√			√			√				√				√	√	√									

01	Abbe, et al. (2011)	02	Abdelhamid and Everett (2000)	03	Aksorn and Hadikusumo (2008)	04	Arboleda and Abraham (2004)	05	Behm, (2005)	06	Borys (2012)	07	Chi, Chang and Ting (2005)	08	Choudhry and Fang, (2008)	09	Fang et al. (2004)	10	Hinze and Teizer (2011)
11	Kartam, Flood and Koushki (2000)	12	Kaskutas et al. (2010)	13	Kines et al. (2010)	14	Lai, Liu, and Ling, (2011)	15	Larsson, Pousette and Törner, (2008)	16	C.W. Liao and Perng (2008)	17	López et al. (2008)	18	Meliá and Becerril(2009)	19	Meliá et al. (2008)	20	Mohamed, Ali, and Tam (2009)
21	Mohamed (1999)	22	Ng et al. (2005)	23	Pousette, Larsson and Törner (2008)	24	Siu, Phillips and Leung, (2004)	25	Suraji et al. (2001)	26	Tam, Zeng and Deng (2004)	27	Toole, (2002)	28	Törner and Pousete (2009)	29	Zheng et al. (2010)	30	Zhou, Fang and Wang (2008)
31	Frone (2009)	32	Henderson et al. (1996)	33	Carpenter et al. (2002)	34	Fang et al. (2006)	35	Parker et al. (2007)	36	Seixas et al. (2008)	37	Masood and Choudhry (2012)								

It is evident from the literature review that the unsafe behaviour of construction workers is influenced by various factors, the relationship between those factors and unsafe behaviour is still to be investigated. However, this study focuses on predicting the unsafe behaviour of a construction worker by studying the influential factors. Thus, the next section of this chapter looks into methods of predictive modelling that can be used to develop an "unsafe behaviour predictive model".

2.8 Predictive modelling

Predictive modelling is identified as a collection of mathematical techniques that formulates a mathematical relationship between targets, responses, or "dependent" variables and various predictor or "independent" variables with the ultimate goal of measuring future values of those predictors and inserting them into the mathematical relationship to predict future values of the target variable (Dickey, 2012). These models come in all shapes and sizes, and there are number of different methods that can be used to create a model. Finlay (2014) categorised these under regression, neural networking, cluster analysis, fuzzy logic and expert systems.

Regression analysis

Regression analysis is done to determine the correlations between two or more variables having cause-effect relations (Uyanık & Güler, 2013). This technique is used for forecasting, time series modelling and finding the causal effect relationship between the variables (Ray, 2015). According to Seber and Lee (2012), linear regression models are statistical models, in which a series of parameters are arranged as a linear combination. Multiple regression analysis utilise statistical computer system approach to forecast change in a dependent variable on the basis of change in one or more independent variables (Garza & Rouhana, 1995). This technique can results in a model that is unique for a given set of data, using multiple independent variables, however, the variables must be reviewed in advance and it is also difficult to use a large number of input variables (Bode, 1998).

Classification and regression trees is a statistical technique that facilitates to effectively address the complexity of variables of non-linear relationships (Breiman, Friedman, Olshen, & Stone, 1984; Sokolow, Foley, Foley, Hastings, & Richardson, 2009). It typically outperforms general linear methods (Seto et. al., 2002). Regression models are often used in applications of financial analysis (Andriyashin, 2005; Breiman et al., 1984), agriculture (Breiman et al., 1984), astronomy (Salzberg, Chandar, Ford, Murthy, & White, 1995) and ecology (De'ath & Fabricius, 2000).

Artificial neural networks

ANNs are relatively new computational tools that have found extensive utilization in solving many complex real-world problems (Basheer & Hajmeer, 2000; Benítez, Castro, & Requena, 1997; Heykin, 2009). These models have the capability of determining the relations between the input and output parameters. It is a model that consists of a set of nodes for processing input data and a set of connections for 'memorizing' information (P.K. Simpson, 1990). Thus, ANN models learn from examples and provides desired results by generating new information. ANN models are suited to analyse complex patterns among variables (Bode, 1998; N. De Silva, Ranasinghe, & De Silva, 2013), and has no restrictions on number of inputs and outputs (Smith & Mason, 1997). But they require large training samples and consumes time in determining the architecture of the model.

ANNs are successfully being used in many areas such as risk analysis (Chen & Hartman, 2000; N. De Silva et al., 2013), prediction of construction project cost and time (Bee-Hua, 2000; Emsley, Lowe, Duff, Harding, & Hickson, 2002; Killingsworth Jr, 1990), customer relationship management, optical character recognition (Chattopadhyay, Dan, Mazumdar, & Chakraborty, 2012), medical decision making (Mazurowski et al., 2008) and telecommunication systems (Frank, Davey, & Hunt, 1999).

Cluster analysis

Clustering can be defined as a division of data in to groups of similar objects (Berkhin, 2006). It is an exploratory tool designed to reveal natural clusters within a data set that would otherwise not be apparent (Ramos, Delgado, Almeida, Simões & Manuel, 2015). For the best possible performance, clustering algorithms require that the data be normalised so that any one attribute or variable will not control the analysis (Williams, 2008). Cluster analysis has been recognised as appropriate for a quick overview of data (Romesburg, 1984; Sneath & Sokal, 1973) and the analysis of large data files (Ramos et al., 2015). However, it is often difficult to know how many clusters likely to be and therefore the analysis may have to be repeated several times (Cornish, 2007). Market research, image analysis, machine learning, image processing and whether report analysis are few applications of cluster analysis (Bijuraj, 2013).

Fuzzy logic

Fuzzy logic is a multi-valued logic which can deal with vague and indecisive ideas (Zahlmann et al., 2000). It is the logic underlying modes of reasoning which are approximate rather than exact (Yager & Zadeh, 2012). Fuzzy logic takes into account that real world is complex and there are uncertainties; everything cannot have absolute values and follow a linear function (Godil, Shamim, Enam, & Qidwai, 2011). However, fuzzy outputs can be interpreted in a number of ways making analysis difficult (Godil et al., 2011). Fuzzy logic has become a valuable tool for a number of different applications ranging from the control of engineering systems to medicine (Tanaka, 1997).

Expert systems

An expert system is an interactive computer-based decision tool that uses both facts and heuristics to solve difficult decision-making problems, based on knowledge acquired from an expert. The basic idea behind expert systems is simply that expertise, which is the vast body of task-specific knowledge, is transferred from a human to a computer and is then stored in the computer and users call upon the computer for specific advice as needed (S.H. Liao, 2005).

The computer can make inferences and arrive at a specific conclusion. Then like a human consultant, it gives advices and explains, if necessary, the logic behind the advice (Turban & Aronson, 2001). These systems have offered the advantages of the efficient use of time in solving problems and extendable knowledge base, but are very expensive and do not have the ability to automate complex procedures (Hart, 1986; Winograd, Davis, Dreyfus, & Smith, 1985). Application of expert systems can be seen in telecommunication (Liebowitz & Pena-Ayala, 2013), psychology (S.H. Liao, 2005), and medicine (Karabatak & Ince, 2009).

2.9 Model for predicting unsafe behaviour of construction workers

As discussed in Section 2.8, there are several different ways of building predictive models, and these utilise different forms of knowledge. Among those, ANNs have emerged as attractive tools for nonlinear process modelling (Zivkovic, Mihajlovic, & Nikolic, 2009). ANN models usually have higher complexity than the other methods (Cherkassky, Friedman, & Wechsler, 1994). Their strength is their ability to make sense out of complex, or nonlinear data to provide robust solutions to problems in a wide range of disciplines, such as prediction, pattern recognition, and function approximation (Cherkassky, Friedman, & Wechsler, 1994; Rosenfeld & Wechsler, 2000).

A study by Moisen and Frescino (2002) identified ANNs to be advantageous for prediction over other methods. When only input-output observations are used, and nonlinear, unknown relationships between inputs and outputs are evident, ANN is accepted as a useful and precise technique (Haykin, 2001; Valyon & Horváth, 2003). Thus, ANNs are in a proven position to analyse large amounts of data in an effective manner and establish characteristics and patterns, where rules or logic is not known. Further, the ANN itself can perceive the relationship and pattern between the inputs, which are the influential factors, and the outputs, which is the unsafe behaviour of construction workers. With the inherent complexity of unforeseen relationships in the prediction of the unsafe behaviour of workers, ANN models could be appropriate representatives of non-linear techniques.

Thus, it can be concluded that ANN is the most suitable technique to predict the unsafe behaviour of a construction worker using influential factors as the input, given that the relationship of these factors with the unsafe behaviour level of a worker is unclear to the point.

2.10 Overview of ANN

ANN belongs to the family of computational architectures inspired by biological brains (Luger & Stubblefield, 1993; McClelland et al., 1986). Such architectures are commonly called 'connectionist systems', and are composed of interconnected and interacting components called nodes or neurones (Leverington, 2009). Dr Robert Hecht-Nielson (as quoted by Caudill, 1987) defined the ANN as a computing system made up of a number of simple, highly interconnected processing elements (i.e. nodes), which process information by their dynamic state response to external inputs via connections. Thus, ANNs are composed of multiple nodes those are connected and interact with one another. These nodes imitate biological neurones of the human brain. They take input data and perform simple operations on the data. The result of these operations is passed to other neurones.

2.10.1 Architecture of ANN

Two types of ANN architecture are identified in the literature as 'Feedforward' and Feedback' (Fletcher, 2016; Welch, Ruffing, & Venayagamoorthy, 2009). The information flow in the feedforward ANN is unidirectional. A unit sends information to another unit from which it does not receive any information (Al-Rahmani, 2012). There are no feedback loops. Feed-forward ANNs tend to be straightforward networks that associate inputs with outputs. Feedback (or recurrent) networks can have signals travelling in both directions by introducing loops in the network. Nodes within layers can be interconnected for recurrent networks, and output signals are transmitted back to the ANN in a variety of loop configurations (Al-Rahmani, 2012). Feedback networks are powerful and can get extremely complicated. Computations derived from the earlier input are fed back into the network, which gives them a kind of memory. Feedback networks are dynamic; their 'state' is continuously changing until they reach an equilibrium point. They remain at the equilibrium point until the input changes and a new equilibrium needs to be found.

2.10.2 Mathematical illustration of ANN

The output of each neurone is a function of its inputs. For every neurone, j, in a layer, each of the inputs, fi, to that layer is multiplied by a predetermined weight, Wij. These are all summed together, resulting in the internal value of this operation, Xj (Mitchell, 1997). This internal value (Xj) is mathematically expressed as;

$$\boldsymbol{Y_j = g\left[\sum\nolimits_{i=0}^{n}\left(w_{ij}.x_i\right)\right]} \qquad \textbf{2-1}$$

Where,

Y_j = Output of the j^{th} neuron

x_i = Input of the i^{th} neuron

w_{ij} = Weight assigned between i^{th} and j^{th} neurons

g = Activation function

Y_j is then biased by a predetermined threshold value, and sent through an activation function, g. This activation function is usually the sigmoid function (Zhang, Patuwo, & Hu, 1998), which has an input to output mapping. The activation function determines that weights how powerful the output should be from the neuron, based on the sum of the input (Mitchell, 1997). Sigmoid function (Equation 2-2) has been used as the activation function which is the most common and differentiable functions in ANNs.

$$\boldsymbol{g(x) = \frac{1}{1+e^{-2s(x+t)}}} \qquad \textbf{2-2}$$

$\boldsymbol{t}$ = Value that pushes the centre of the activation function away from zero.

$\boldsymbol{s}$ = Steepness parameter.

The resultant output is an input to the next layer or it is a response of the ANN if it is the last layer.

2.10.3 Training the ANN

To train an ANN to perform a task, the weights of each unit must be adjusted in such a way that the error between the desired output and the actual output is reduced. This process requires the ANN to compute the error derivative of the weights. In other words, it must calculate how the error changes as each weight is increased or decreased slightly. Rumelhart, Hinton, and Williams (1986) proposed an efficient algorithm for training multilayer feedforward networks, called the backpropagation algorithm. The backpropagation algorithm first sets random weights for each training sample, and then modifies them as to minimise the mean squared error between the network's prediction and actual value (Mitchell, 1997). These weights modifications propagated in 'backwards' direction, that is, from the output layer, through each hidden layer down to the first hidden layer. Hence, the name backpropagation.
After propagating an input using the network, the difference is calculated, and the error is propagated back through the network while the weights are adjusted to make the error smaller as possible.

The error over an entire set of training samples (i.e., over one iteration) is calculated by summing all errors. The backpropagation process goes on until a certain stop criterion is reached. Network error (E_{net}) is denoted by Equation 2-3.

$$\mathbf{E_{net}} = \frac{\mathbf{1}}{\mathbf{2n}}\sum_{\boldsymbol{j=1}}^{\boldsymbol{n}}\left(\boldsymbol{T_j} - \boldsymbol{C_j}\right)^2 \qquad \textbf{2-3}$$

Where;

n = The number of training samples

T_j= The target output of the jth training sample

C_j= The corresponding computed output

A network error of zero, meaning that the estimator predicts observations of the parameter with perfect accuracy, is the ideal, but is practically never possible (Trnavac, n.d.). Thus, when network error reaches a certain limit, the training is stopped (Mitchell, 1997).

2.11 Summary

This chapter focused on the literature regarding safety in the construction industry, causes of construction accidents, the unsafe behaviour of construction workers, and the factors influencing unsafe behaviours. According to the literature findings, the construction industry is one of the most hazardous industries worldwide and is swarmed with accidents. The leading cause of construction accidents was identified as the unsafe behaviour of construction workers. The study isolated 15 prominent acts that fall under unsafe behaviour of construction workers and a list of 15 factors that influence unsafe behaviour, under three main constitutes as a person, process and place.

Age, gender, experience, education level, attitudes towards safety, income, alcohol/drug abuse, and psychological distress were identified and discussed under the person constitute. Hazardous operations on site, unsafe conditions on site, and use of hazardous equipment were the factors identified under the process constitute while the place included the availability of directive safety procedures and rules, management commitment, employee involvement in safety and safety communication.

The available predictive modelling techniques and the suitability of ANN for this study were also reviewed in the chapter together with the overview of the ANN in general. The next chapter elaborates the research methodology adopted.

CHAPTER 3

RESEARCH METHODOLOGY

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 Introduction

The research problem statement and the main objectives were detailed in Chapter 1. Chapter 2 presented the literature findings of the study. The purpose of this chapter is to discuss the research design, explain research process adopted and clarify the measures taken to ensure research validity and reliability. Firstly, in Section 3.2 the focus is on the importance and necessity of adapting a research design to ensure that the evidence obtained in the research process enables to answer the research questions clearly. Research paradigm and strategy adopted accordingly are explained in the Section 3.3 and Section 3.4 respectively. Subsequently, Section 3.5 discusses the research method of the study, under which a detailed elaboration of data collection and analysis is presented. A stepwise description of the ANN model development, demonstration, and validation is provided under data analysis.

3.2 Research design

According to Owens (2002), research needs a design or structure before data collection or analysis can commence. The research design is the logical sequence that connects the empirical data to a study, initial research questions and, ultimately to its conclusions (R.K. Yin, 2009). R.K. Yin (2009) further asserted that a research design helps to avoid the situations in which the research evidence does not address the initial research questions, as the function of a research design is to ensure that the evidence obtained enables to answer the original question as unambiguously as possible. It specifies the methods and procedures for collecting and analysing the needed information (Adams, Khan, Raeside, & White, 2007). However, as per Creswell (2009), design is based on the nature of the research problem or issue being addressed, the researcher's personal experiences, and the audiences for the study.

Creswell (2009) defines research design as the plan and procedures to conducting research involving the intersection of three elements: philosophical worldview (i.e. methodological paradigm), strategies of inquiry (i.e. research strategy), and specific methods (i.e. research methods). Three types of research design are in common use: quantitative; qualitative; and mixed method (Creswell, 2009; Fellows & Liu, 2008). In selecting an appropriate one for a given study, Creswell (2009) proposes that the decision should be informed by the three elements of research design. To aid the choice of an appropriate research design for this study, Creswell's (2009) framework (Figure 3-1) served as a useful guide. In the sections that follow, the elements of this framework are reviewed in relation to the study.

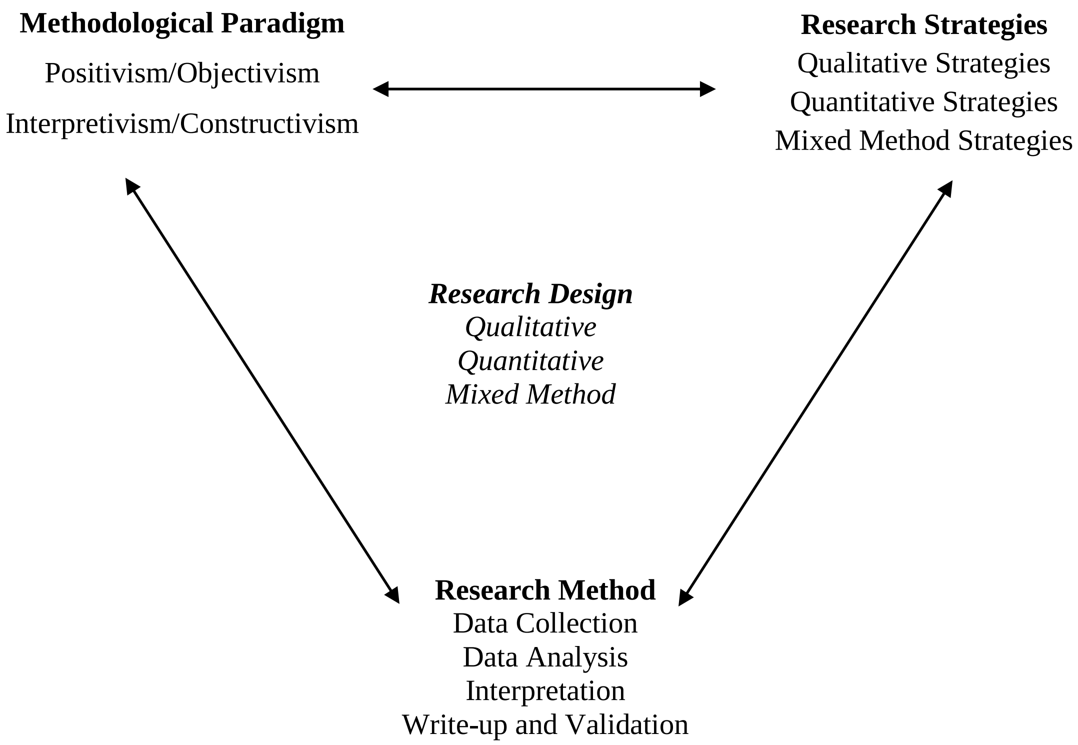

Figure 3-1: Framework for research design

Source: (Creswell, 2009)

3.3 Methodological paradigm

The term paradigm refers to a commonly shared set of assumptions, values and concepts within a community, which constitutes a way of viewing reality (Pollack, 2007). The term “philosophical worldview” (Creswell, 2009) is perceived for paradigm and is considered to mean “a basic set of beliefs that guide action” (Guba, 1990). These methodological paradigms shape the research strategies and methods adopted by researchers (Pollack, 2007).

The two prominent paradigms that are in use are positivism; and interpretivism (Bailey, 1987; Fellows & Liu, 2008). Interpretivists contend that only through the subjective interpretation of and intervention, in reality, can that reality be fully understood. The study of phenomena in their natural environment is the key to the interpretivist philosophy, that the reality is subjective and interior to the people (Easterby-Smith, Thorpe, & Lowe, 2002).

Interpretivists avoid rigid structural frameworks such as in positivist research and adopt a more personal and flexible research structures (Carson, Gilmore, Perry, & Gronhaug, 2001) which are receptive to capturing meanings in human interaction (Black, 2006) and make sense of what is perceived as reality (Carson et al., 2001). Positivists believe that reality is stable and can be observed and described from an objective viewpoint, i.e. without interfering with the phenomena being studied. They researchers seek objectivity and use consistently rational and logical approaches to research (Carson et al., 2001; Hudson & Ozanne, 1988).

Table 3-1 provides further contrasting implications of choice between positivism and interpretivism.

Table 3-1: Contrasting implications between positivism and interpretivism

Positivism	**Interpretivism**
The observer must be independent	The observer is part of what is being observed
Demonstrates causality	Aim is to increase general understanding of the situation
Research progresses through hypothesis/prior formulation	Research progresses through gathering rich data from which ideas are induced
Concepts need to be operationalized so that they can be measured	Concepts should incorporate stakeholder perspectives
Unit of analysis should be reduced to simplest terms	Unit of analysis may include the complexity of whole situations
Generalisation through statistical probability	Generalisation through theoretical abstraction
Requires large sample selected randomly	Requires small number of cases chosen for specific reasons

Source: (Easterby-Smith et al., 2002)

Saunders, Lewis, and Thornhill (2009) explained three major ways of thinking about research philosophy: ontology, epistemology and axiology. Each contains important differences which will influence the way in which one thinks about the research process. Table 3-2 illustrates the ways of thinking about research philosophy.

Table 3-2: Ways of thinking about research philosophy

	Positivism	**Interpretivism**
Ontology: *the researcher's view of the nature of reality or being*	External, objective and independent of social actors	Socially constructed, subjective, may change
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions
Axiology: *the researcher's view of the role of values in research*	Research is undertaken in a value-free way, the researcher is independent of the data	Research is value bound, the researcher is part of what is being researched

Source: (Saunders et al., 2009)

3.3.1. The research paradigm adopted

The key research questions influence the type of paradigm that has to be adopted (Pollack, 2007; Remenyi & Williams, 1998). From the research questions posed in Chapter 1, it is evident that they are laden with measurement. Ontologically, the research assumes a realist viewpoint where construction workers' unsafe behaviour is a function of different objective influential factors. Also, this research assumes that only the collection of data and the understanding of those data can provide a credible answer to the research questions. Thus, it takes an objective viewpoint epistemologically.

Although, a pilot study was undertaken to validate the literature findings to Sri Lankan context, the interviews conducted were structured. Each expert got the same set of questions, in the same way, in the same order. The guidelines were based on the number of unsafe acts and influential factors and their applicability to Sri Lankan context. Furthermore, in the main survey, the data collection instrument used was a self-administered questionnaire. Hence, the research was undertaken in a value-free way, where the researcher was independent of the data and maintains an objective stance. Hence, in an axiological viewpoint, the research is value-free. Thus, by considering all the ways of thinking about the research philosophical paradigms, it is logical to adopt positivism as an overarching worldview for the phenomenon being investigated. By adopting positivism, the degree of influence of a factor on the unsafe behaviour of construction workers can be regarded as a single reality which can then be observed and assessed objectively.

3.4 Research strategy

The research strategy provides specific direction for procedures in a research design (Creswell, 2009). The three common research strategies are qualitative, quantitative and mixed method strategies. These strategies are discussed below.

3.4.1. Qualitative research strategies

Qualitative research provides a means of exploring and understanding the meaning individuals or groups ascribe to a phenomenon (Creswell, 2009). It is useful in answering research questions relating to ‘how’ and ‘why’ (Fellows & Liu, 2008). The qualitative process of research is inductive in relation to theory and literature, and it is usually rooted in the interpretivist philosophical position (Sutrisna, 2009). The samples collected are often small as the focus is obtaining in-depth meaning and not generalisation (Manu, 2012).

3.4.2. Quantitative research strategies

Quantitative research is a means of testing objective theories or prior formulations by examining the relationship between variables. It involves numerical and objective measurements to address questions. It is thus useful in answering research questions relating to ‘what’, ‘how much’ and ‘how many’ (Fellows & Liu, 2008). The quantitative process of research is deductive in relation to theory and literature, and it is usually rooted in the positivist philosophical position (Sutrisna, 2009). It involves the formulation of hypothesis or prior formulations in the form of a conceptual model based on theory and literature with subsequent collection and analysis of data to verify those prior formulations (Manu, 2012).

The samples collected in quantitative research are often large and representative. This means that quantitative research results can be generalised to a larger population (Manu, 2012). There are two prominent quantitative strategies: survey; and experiment which provide a quantitative or numeric description of trends, attitudes, or opinion of a population by studying a sample of that population (Creswell, 2009). It includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection with the intent of generalising from a sample to a population (Babbie, 1990).

3.4.3. Mixed method strategies

Mixed method research is an amalgam of qualitative and quantitative strategies in a single study (Morse, 2003; Tashakkori & Teddlie, 1998). It, therefore, involves the use of both qualitative and quantitative methods of data collection and analysis in a single study (Creswell, 2009). Mixed method research is normally appropriate in research where due to the nature of the research problem being investigated, it is possible to collect both qualitative and quantitative data, the analysis of which would offer a better and deeper understanding of a phenomenon (Creswell, 2009).

3.4.4. The adopted research strategy

Provided that quantitative research is usually embedded in the positivist paradigm (Creswell, 2009; Sutrisna, 2009) which is the adopted paradigm for this study, the quantitative strategy naturally emerges as the main strategy of inquiry for this research (Creswell, 2009; Sutrisna, 2009).

Furthermore, the suitability of quantitative inquiry for answering questions relating to what, how much and how many (Kraemer, 2002; Yin, 2003) further reinforces its suitability for this research given that the research questions put forward in this study largely suggest measurement of the degree of influence of the factors on unsafe behaviour. This justifies the selection of quantitative strategy. Also, the need to test the espoused hypotheses regarding the potential of factors to influence unsafe behaviour is consistent with the quantitative approach. In the main, the quantitative research strategy thus appears to be a prime strategy for delivering this research.

As mentioned in Section 3.4.2, two common research strategies are used in quantitative research: experiment; and survey. Experiments would not be ideal for this study because they are usually carried out in a laboratory setting where the investigator can manipulate variables of interest directly, precisely and systematically (R.K. Yin, 2003). This research was conducted in the construction industry with no controlled parameters. Hence, the suitability of experiment for this study was questionable

Furthermore, this study does not apply experimental strategy even though it is quantitative. This research investigates a selected sample of the population through cross-sectional studies, using semi-structured interviews and questionnaires for data collection. Thus, survey approach emerges as more appropriate as it refers to a method which emphasises quantitative analysis, where data for a large number of establishments are collected.

Additionally, the survey approach is highly appropriate where there is an involvement of analysing numerical data to conduct an objective study and construct algebraic models in an attempt to identify casual relationships between variables abstracted through hypothesis or research questions developed (Yin, 2009). Moreover, surveys can accurately document the norm, identify extreme outcomes, and delineate associations between variables in a sample (Gable, 1994).

Quantitative research is a means of testing objective theories or prior formulations by examining the relationship between variables as mentioned in Section 3.4.2. It involves numerical and objective measurements to address questions relating to what, how much and how many (Fellows & Liu, 2008). The study involved a systematic application of the assessment outline as follows:

1. Assessing the unsafe behaviour of a construction worker
2. Assessing the impact of influential factors on unsafe behaviour

This study clearly defines the objectives that the outcome is to determine the collective impact of factors influencing construction workers' unsafe behaviour. In addition, the relevant research questions were developed based on previous literature by identifying the dependent and independent variables, which should be reviewed to answer the research questions by collecting data in an uncontrolled parametric environment from a large number of individuals.

Further, Gable (1994) recommended the survey approach to discover relationships that are common across organisations and hence to provide generalisable statements about the object of study. Saunders et al. (2009) added to the argument by asserting that surveys are useful in describing the characteristics of a large population. All the argument discussed above point in the direction that the survey approach under the quantitative phenomenon is the most appropriate research strategy to conduct this study.

A cross-sectional survey was thus chosen, as the most appropriate strategy for the study. It provides a quantitative or numeric description of the opinion of a population by studying a sample of that population. This approach has been used in many construction health and safety studies (Kheni, Dainty, & Gibb, 2008; Langford et al., 2000).

3.5 Research method

Once the best-suited research approach was decided upon, the survey design was fittingly set-up. The research process was designed to be carried out in four phases as illustrated in Figure 3-2.

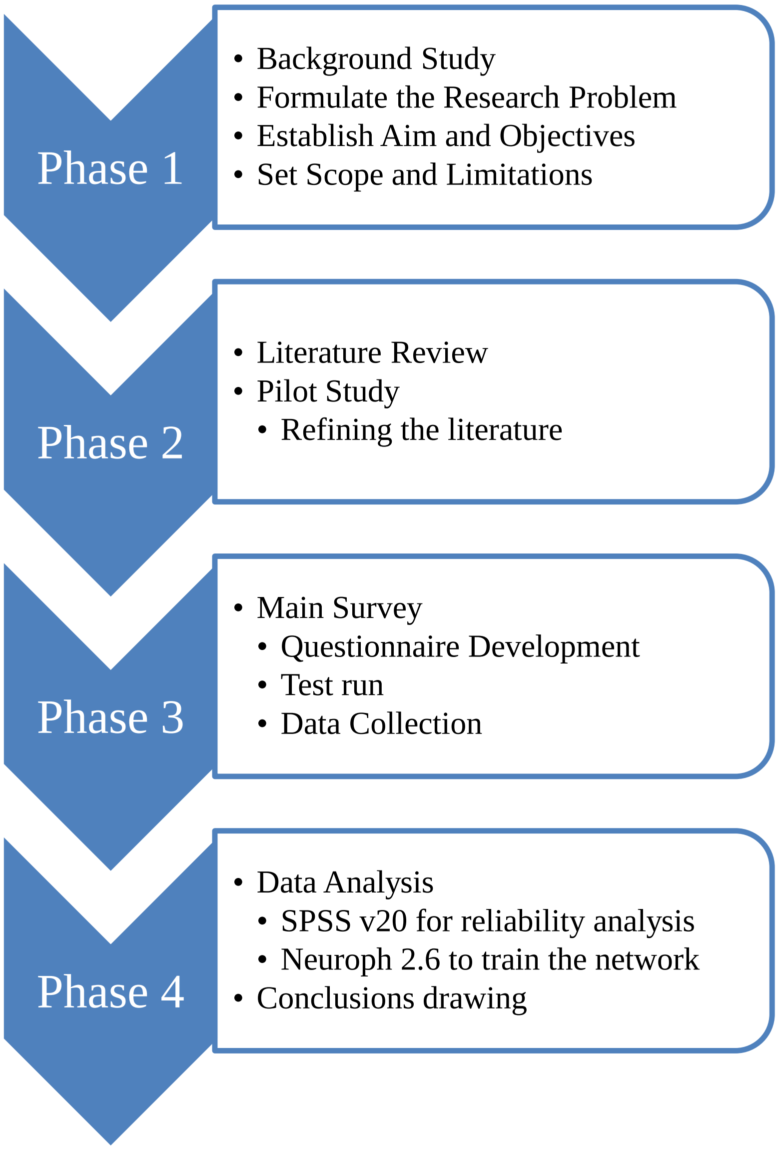

Figure 3-2: Research process

3.5.1. Phase 1: Background study

The first phase specifically focused on the research area. The primary purpose of the phase was to identify the main concepts of the study. The background study was carried out through books, journals, articles, publications and opinions gathered from professionals, which were useful in gaining an early understanding of the research problem (refer Section 1.1). Then, the aim and the objectives of the research were formulated accordingly together with the scope and limitations of the study.

3.5.2. Phase 2: Literature review and the pilot study

A literature review was carried out to gain an in-depth understanding of the research problem. Thus, it was focused on areas to enhance knowledge to gather information around the research questions posed in the first phase of the research. Literature synthesised unsafe behaviour of construction workers, factors influencing unsafe behaviour and the techniques to develop a predictive model in accordance with the research problem. Under three main categories, a total of 15 factors influencing unsafe behaviour and a total of 15 unsafe acts by a construction worker were identified in the literature review, and ANN was decided as the best-suited method to predict the unsafe behaviour of construction workers based on the influential factors.

In order to get the literature findings validated and further to identify specific variables that could be relevant under local practices, a pilot study was carried out. Interviews were held with five managerial level experts, each having more than fifteen years of experience the fields of occupational safety and projects management in the construction industry. Table 3-3 presents the interviewee profile of the pilot study.

Table 3-3: Pilot study interviewee profile

Interviewee (Expert)	Designation	Years of experience in construction industry
E1	General Manager – Projects	20+
E2	Safety Engineer	15+
E3	Deputy General Manager – Project Coordinating	24+
E4	Project Manager	20+
E5	Manager EHS	16+

Interviews were structured, which is quantitative research method commonly employed in survey research. This guaranteed that answers can be reliably collected and that comparisons can be made with confidence between the responses (Trueman, 2016). (Interview guidelines are detailed in Appendix 1). Each interview was held for 30-45 minutes and followed three steps; Introduction to the research, unsafe acts and influential factors. At the beginning of the discussion, a brief introduction of the research was provided to the experts for the purpose of explaining the background and the objectives of the research. Then the identified 15 unsafe acts were introduced to the experts for review, followed by the 15 influential factors of unsafe behaviour. Unsafe acts and influential factors were discussed and elaborated with regards to the Sri Lankan context, and specific changes necessary were elicited.

3.5.3. Phase 3: Main survey

3.5.3.1. Selection of the data collection technique

Participant observations, interviews, questionnaires and document surveys can be applied as data collection techniques in research (Saunders et al., 2009). As per research (Ackroyd & Hughes, 1981; Popper, 1959), questionnaire is the most suitable data collection technique to be adopted when large amounts of information has to be collected from a large number of people. A questionnaire allows the researcher to collect data in a short period and in a relatively cost effective way, with limited effect on its validity and reliability.

This study required a large amount of information from a large sample which can be easily quantified and be analysed with maximum objectivity to determine the relationship between the identified dependent and independent variables. Thus, a questionnaire was selected as the suitable data collection technique for this research.

3.5.3.2. Questionnaire development

A crucial part of good research design concerns making sure that the questionnaire design addresses the needs of the research (Burgess, 2001). The internal validity and reliability of the data collected and the response rate achieved depend, to a large extent, on the design of questions, and how they structured and presented (Saunders et al., 2009). As per Burgess (2001), respondents are more likely to commit to answer a questionnaire when they see it as interesting, of value, short, clearly thought through, and well presented. Thus, the questionnaire (refer Appendix 2) was developed including closed ended questions matching to the anticipated quantitative outcome of the research.

Further, the questionnaire was designed to be ‘respondent-friendly’ in order to maximize the response rate, which is widely recognized as being particularly low in construction management research (Hong, 2002). The questionnaire of this research was designed in three parts. First part of the questionnaire was designed to capture the information of background information and two influential factors (age and experience) of the respondents which were categorised under person constitute. The second part listed down the acts identified under unsafe behaviour and thus 15 acts were presented with a 1-5 Likert scale; so that the respondent will have to score the acts they engage in according to the likelihood of each. A Likert scale is an ordered scale from which respondents choose one option that best aligns with their view. Likert scales may meet the researcher’s needs when they have attitude, belief, or behaviour items (McLeod, 2008).

Thus, for the purpose of quantifying USBS for this model, the subjective estimates were obtained on a 5-point Likert scale. In this scale, numerical scores of 1-5 were assigned with verbal descriptions to minimize the ambiguity associated with these scales as discussed by Meyer and Booker (2001) (refer Figure 3-3).

Unsafe Acts	S_1 (1) = None of the time (never)
	S_2 (2) = A little of the time (few times in your work life)
	S_3 (3) = Some of the time (not frequent but come about when you work
	S_4 (4) = Most of the time (often when you work)
	S_5 (5) = All of the time (Every time/habitually when you work)

Figure 3-3: Scoring of unsafe acts

The third part of the questionnaire was designed to collect data on influential factors identified in the study. Questionnaire included 14 influential factors, and six factors were assessed using three validated questionnaires as follows.

1. CAGE-AID test which was developed and validated by Brown and Rounds (1994) was used to assess alcohol/drug use of individuals. It provided following four simple questions;
   - Q1. Have you ever felt you ought to cut down on your drinking or drug use?
   - Q2. Have people annoyed you by criticising your drinking or drug use?
   - Q3. Have you felt bad or guilty about your drinking or drug use?
   - Q4. Have you ever had a drink or used drugs first thing in the morning to steady your nerves or to get rid of a hangover?

2. Kessler (K6) developed by Kessler et al. (2002) was used to assess nonspecific psychological distress experienced in the most recent 4-week period. It provided six questions that ask about the feelings (sad, nervous, restless or fidgety, hopeless, everything is an effort, worthless) during the past month (refer Appendix 3), with a self-report scale of five values:
   - *None of the time - scores 1*
   - *A little of the time - scores 2*
   - *Some of the time - scores 3*
   - *Most of the time - scores 4*
   - *All of the time - scores 5*

3. Health and safety climate survey tool developed by HSE (1998) was adapted to assess the influential factors of organisational safety culture (Safety Procedures and rules, Management Commitment, Employee involvement in safety, and Safety Communication). It consisted seven set of questions assessing various aspects of organisational safety culture and climate (refer Appendix 4).

The CAGE-AID questionnaire is recommended as a screening instrument for detecting alcohol/drug abuse, and has previously used in similar capacity (Basu, Ghosh, Hazari, & Parakh, 2016; Leonardson et al., 2005; Mdege & Lang, 2011). Item responses on the CAGE-AID are scored 0 or 1, with a higher score indicating alcohol or drug use problems. Thus, the severity of the alcohol/drug abuse were measured using total score of the CAGE-AID test, categorised in to five classes from 1 to 5. Class 1 indicated no alcohol/drug abuse while class 5 indicated severe abuse.

In Kessler K6, the psychological distress was measured using the six-item measure developed by Kessler et al. (2002). It assesses the nonspecific psychological distress experienced in the most recent 4-week period. It is one of the most widely used measures, for either screening or severity for psychological distress (Mitchell & Beals, 2011). Previous studies have supported the sensitivity and validity of the scale (Carlisle & Parker, 2014).

As described in detail in Kessler et al. (2003), the scale was designed to be sensitive around the threshold for the clinically significant range of the distribution of nonspecific distress in an effort to maximise the ability to discriminate cases of serious mental illness (SMI) from non-cases. In this scale, total scores range from 6 indicating (no distress) to 30 (indicating severe distress). People who score low range are likely to be well. People who score mild to moderate range are likely to have a mild to moderate mental health disorder. People who score in the high range are likely to have a severe mental health disorder and are strongly encouraged to seek face to face help from their health professional (Andrews & Slade, 2001).

The Kessler K6 fitted with the rhythm of the questionnaire and the intended purpose well. It was thus adopted to measure the level of psychological distress of the construction workers in this study by dividing the scores a worker can obtain in to five classes.

Health and Safety Climate Survey Tool is a generic tool that can be used in any industry sector to assess the safety culture dimensions (Cox & Flin, 1998; Davies, Spencer, & Dooley, 2001; Mearns, Whitaker, & Flin, 2001). Thus, the study adapted the tool by incorporating these questions under the four influential factors of unsafe behaviour those fall under 'Place' as appropriate. The total scores were summed up and classified under five classes, 1 representing the best case scenario and 5, the worst case scenario for safety of the workers.

Closed survey items, those consist only of requests for an answer with explicitly mentioned answer categories (Saris & Gallhofer, 2007), were used to cover the data collection of the rest of the influential factors. These responses were presented as five choices where 1 representing best case scenario and 5, the worst-case scenario of each factor when it came down to the unsafe behaviour of workers according to the literature and pilot study findings.

Two experts from safety industry and academia, both having more than 15 years of experience in their respective fields and excellent track records, reviewed and fine-tuned the questionnaire so that it would proficiently capture data relevant to the research problem.

After finalising the English medium questionnaire, it was proofread by a professional proof-reader and then was translated by a professional translator to Sinhala language.

3.5.3.3. The test run

Test run is necessary to show the methodological rigour of a survey (Munn & Drever, 1995). Hence, as the first stage of the survey process, a test run was conducted to assess the clarity and comprehensiveness of the questionnaire. The developed questionnaire was thus distributed among ten randomly selected construction workers of a high-rise building project undertaken by a reputed C1 contractor within the Colombo district as a test run. The response rate of the test run was 90% as all, but one respondent was keen on participating and fully completing the questionnaire.

Further, there was no indication from respondents that the questions given in the questionnaire were difficult to understand. However, they preferred to answer the questionnaire on their own and showed reluctance to give away any form of identity as the questionnaire consisted of information about noncompliance to safety rules, alcohol/drug abuse and internal safety culture of the organisation. Thus, the need for the survey to be conducted as a self-administered questionnaire survey was proven in the test run. Overall, the test run indicated that the questionnaire was suitable to be administered in a larger survey (refer Appendix 2 for the main survey questionnaire developed).

3.5.3.4. Sampling

Construction workers are the target source of data of this study and hence constitute the population at a glance. As it was impractical to collect data from all the construction workers in Sri Lankan construction sector as it is an enormous sample, sampling was necessary because of the constraints of time and cost (Babbie, 1990). Saunders et al. (2009) identified two types of sampling, namely; representative sampling and judgmental sampling. Judgmental sampling involves the choice of subjects who are well equipped with information that will be relevant to the researcher's focus.

Judgmental sampling technique is employed especially when the desired population for the study is uncommon or very difficult to locate and employ. This technique is, therefore, useful when a limited number or category of people have the information that is sought for by the researcher (Annum, 2016). Saunders et al. (2009) explained that with representative samples, the chance, or probability, of each case being selected from the population is known and is usually equal for all cases.

Also, representative sampling is often associated with the survey and experimental research strategies. Hence, when weighing the representative and judgmental sampling methods in-line with the nature of the study and its population, representative sampling appeared to be the most suitable sampling method to be adopted in this study.

Construction Industry Development Authority (CIDA) (2016) categorises the Sri Lankan construction industry based on the nature and financial status of the projects undertaken. Schemes "C" (Building and Civil Engineering), "EM" (Electrical Mechanical Services), "SP-C" (Specialized Constructions) and "GP" (Piling) are introduced in the Guidelines for Grading of Construction Contractors by CIDA (2016) (refer Table 3-4).

Table 3-4: National registration & grading scheme for construction contractors

Speciality	Grade	Financial Limit (Rs. Million)	Registration Fee per year (Rs.)
Building Construction Highway Construction Bridge Construction Water Supply and Sewerage Irrigation and Drainage Canals Dredging and Reclamation Storm Water disposal and Land Drainage Maritime Construction Heavy Construction (Areas to be Specified)	CS2	X > 3000	500,000.00 + VAT
	CS1	3000 ≥ X > 1500	150,000.00 + VAT
	C1	1500 ≥ X > 600	75,000.00 + VAT
	C2	600 ≥ X > 300	42,000.00 + VAT
	C3	300 ≥ X > 150	37,000.00 + VAT
	C4	150 ≥ X > 50	31,000.00 + VAT
	C5	50 ≥ X > 25	26,000.00 + VAT
	C6	25 ≥ X > 10	20,000.00 + VAT
	C7	10 ≥ X > 05	15,000.00 + VAT
	C8	05 ≥ X > 02	8,000.00 + VAT
	C9	02 ≥ X	6,000.00 + VAT
Electrical & Mechanical Services (EM)	EM 1	X ≥ 50	31,000/- + VAT
	EM 2	50 ≥ X > 25	26,000/- + VAT
	EM 3	25 ≥ X > 10	20,000/- + VAT
	EM 4	10 ≥ X > 02	15,000/- + VAT
	EM 5	02 ≥ X	5,650/- + VAT
Specialized Construction Contractors (SP-C)	SP1	X ≥ 50	31,000/- + VAT
	SP2	50 ≥ X > 25	26,000/- + VAT
	SP3	25 ≥ X > 10	20,000/- + VAT
	SP4	10 ≥ X > 02	15,000/- + VAT
	SP5	02 ≥ X	5,650/- + VAT
Piling	SP1	X ≥ 50	31,000/- + VAT
	SP2	50 ≥ X > 25	26,000/- + VAT
	SP3	25 ≥ X > 10	20,000/- + VAT
	SP4	10 ≥ X > 02	15,000/- + VAT
	SP5	02 ≥ X	5,650/- + VAT

Source: (CIDA, 2016)

Since the safety conditions, risks and the ramifications of construction accidents vary with the complexity and scale of the project (Burkhart, et al., 1993; H. Lee, Lee, Park, Baek, & Lee, 2012), the study focused on scheme C: Building Contractors.

Super grades were excluded from the sample as only a handful of companies have registered under the scheme. According to the industry experts, the difference among C1 contractors and the companies with grades bellow C1 on safety management is huge and cannot be overlooked. Thus, C1 Building contractors were selected as the most appropriate sampling frame for data collection considering the scale of operations which are complex and use a large number of heavy machinery and thus involve high safety risks.

However, considering the time constraint, the C1 building contractors who has undertaken high-rise building projects which are meant to as highly complex and has a high potential for safety risks, within the Colombo district were selected as the population (refer Figure 3-4).

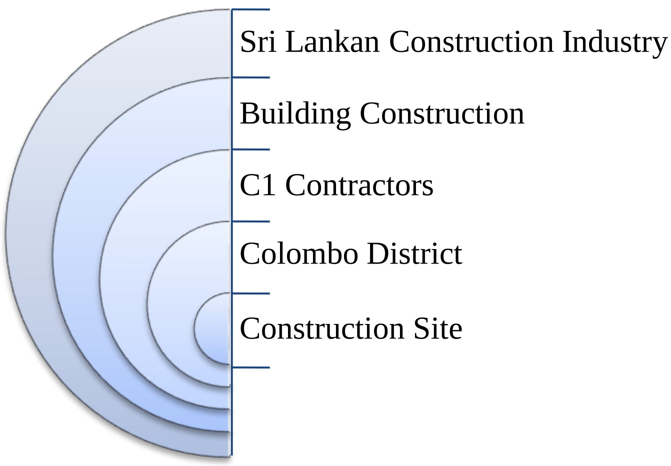

Figure 3-4: Sample selection

Out of the 54 C1 contractors registered in CIDA, a total of 20 C1 Building contractors running projects within Colombo district were recognised by examining the contractors’ list. Similar high rise building construction sites managed by the selected contractors were identified, and from each site, 20 construction workers were randomly selected using simple random sampling. Hence, the size of the target sample was 400.

3.5.3.5. Conducting the survey

Once the target sample was decided upon, the questionnaires were distributed to the potential respondents of the selected sites. Both manual distribution and emailing were used depending on the preference and flexibility of the site management. Printed sets of questionnaires were delivered manually to the respondents via the site management in most cases. Four sets, however, had to be emailed to the safety officers of the respective sites to be distributed among the respondents, with clear and concise instructions on respondent selection. In most cases researcher was there at the site as the respondents attended to the self-administered questionnaire. The data collection was extremely time-consuming as the appointments with the site management staff were constantly rescheduled due to the busy nature of the construction industry and the sites' inability to release 20 workers at a time to attend the questionnaire survey. In some occasions, the researcher had to visit the site a number of days to collect responses from the targeted number of workers. In addition, there were cases of illiteracy of respondents and the researcher had to read out the questions so that the worker can understand and respond. The responses were validated from a supervisory level employee at each site to improve the accuracy.

The survey resulted a response rate of 71%. According to a study by Takim, Akintoye, and Kelly (2004), the response rate norm for questionnaire survey is 20-30%., and 50% is regarded as an acceptable response rate in social research surveys (Nulty, 2008). Baruch (1999) studied the response rates reported by 141 published studies and 175 surveys in five top management journals published in 1975, 1985 and 1995. According to the findings of the study, the response rate of 60% or more is both desirable and achievable. Therefore, the response rate of 71% reached in this survey was considered adequate for the purpose of data analysis.

3.5.4. Phase 4: Data analysis

The data collected through a pilot study and questionnaire survey were subjected to data analysis. Data analysis phase consists of three stages, content analysis, reliability analysis of the scale used in data collection and the unsafe behaviour prediction model development and training using ANN (refer Figure 3-5).

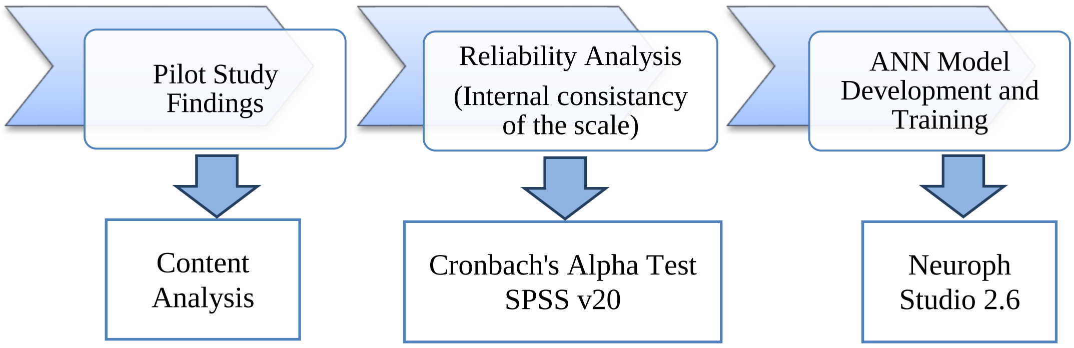

Figure 3-5: Data analysis techniques adopted

3.5.4.1. Content analysis

According Liamputtong (2009), content analysis can be identified as an analytic approach which assists in quantifying the collected qualitative data logically and a replicable manner in terms of pre-determined categories. The purpose of the pilot study was to get the information obtained in literature validated to Sri Lankan context. Thus, a manual content analysis of the interview transcripts was conducted to identify the missing information from literature those are specific to Sri Lankan context and the information those are not relevant considering the context.

3.5.4.2. Analysis for data reliability

The failure to consider data reliability in substantive research may exact a toll on the interpretations of research studies (Thompson, 1994). Reliability pertains to the consistency of scores. The less consistency within a given measurement, the less useful the data may be in the analysis (Thompson, 1994). Cronbach's (1951) alpha was developed based on the necessity to evaluate items scored in multiple answer categories. It is the most common measure of internal consistency ("reliability"), commonly used when the study has multiple Likert questions in a survey/questionnaire that form a scale and scale reliability is to be assured (Bonett & Wright, 2015).

Cronbach's alpha reliability describes the reliability of a sum (or average) of q measurements where the q measurements may represent q raters, occasions, alternative forms, or questionnaire/test items (Bonett & Wright, 2015). Calculating alpha has become common practice when multiple-item measures of a concept or construct are employed (Tavakol & Dennick, 2011). It can be used for dichotomous and continuously scored variables. There are different reports about the acceptable values of alpha, ranging from 0.70 to 0.95. (Bland & Altman, 1997; DeVellis, 2003) (refer Table 3-5). A low value of alpha could be due to a low number of questions, poor interrelatedness between items or heterogeneous constructs (Tavakol & Dennick, 2011).

Table 3-5: Values of Cronbach's alpha

Cronbach's Alpha	**Internal Consistency**
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

Source: (Bland & Altman, 1997; DeVellis, 2003)

Two datasets were collected in the questionnaire survey on unsafe acts and influential factors. All the collected data were coded to fall on a scale of 1 to 5, and the Cronbach's alpha was calculated using SPSS V20 to test the consistency of the scales used throughout the research (refer Section 4.3).

After the reliability analysis had proved the consistency of the scales used and the datasets to be appropriate for analysis, the next step was to develop and train an ANN to predict the unsafe behaviour of construction workers utilising the collected data. Section 4.4.3.1 details the development and training of the network.

3.5.4.3. Predictive model of USBS using ANN

The theoretical model of the USBS of construction workers was derived based on the unsafe acts committed related to conducting, ergonomics, and tools and equipment by the workers due to the fourteen influential factors related to individual dynamics (person), work environment (process) and organisational safety culture (place) as illustrated in Figure 3-6.

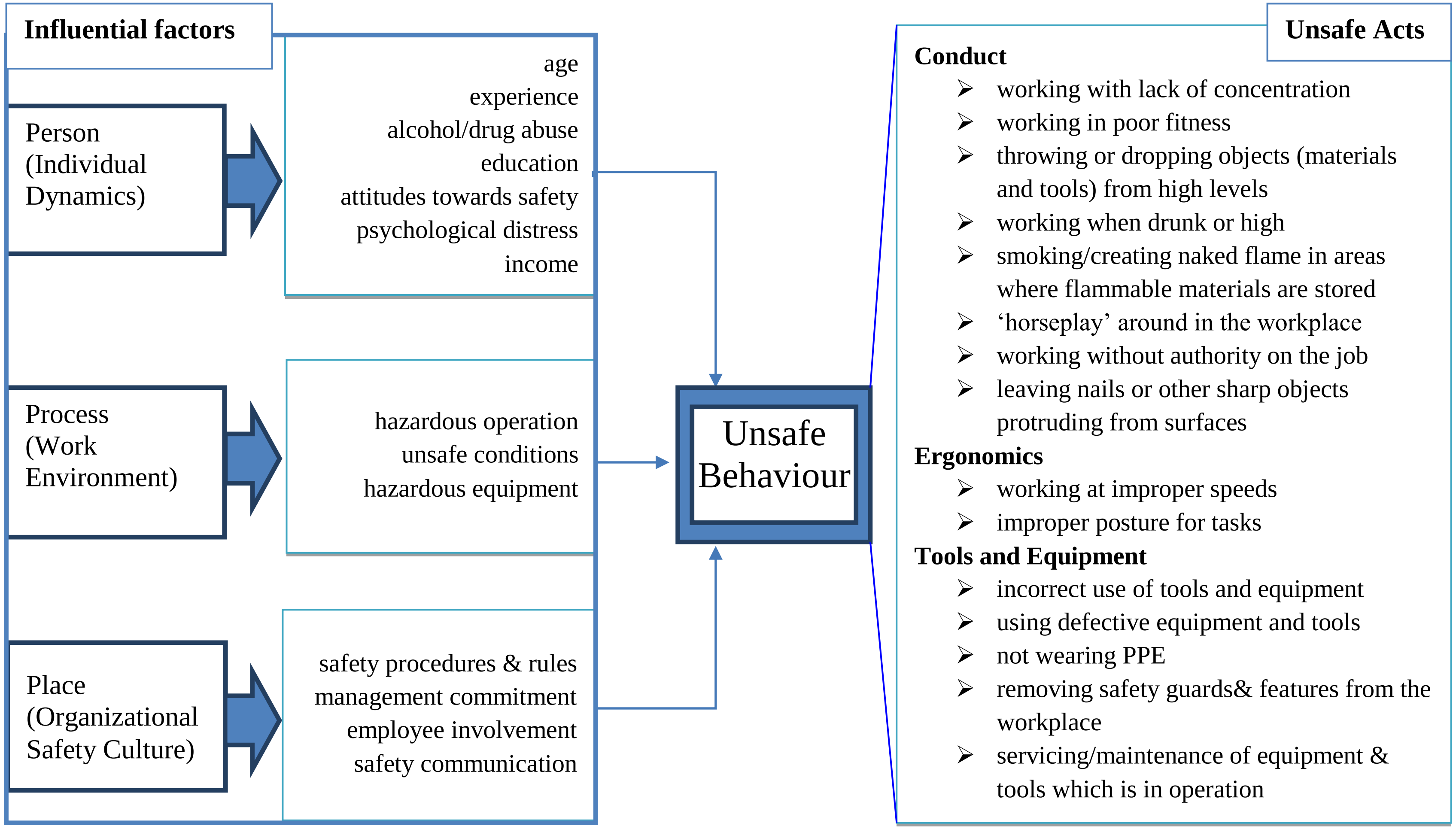

Figure 3-6: Theoretical model of unsafe behaviour of construction workers

The model was developed using ANN applications. As mentioned in Section 2.8, there are many methods available to develop predictive models. Considering the complexity of the problem (Basheer & Hajmeer, 2000), and the unknown relationship between independent and dependent variables (Bode, 1998; Smith & Mason, 1997) ANN was applied in the research. The following steps were carried out in developing the model.

Step 1: Modelling influential factors

The study identified 14 influential factors of the unsafe behaviour of construction workers (refer Figure 3-6). It was assumed that the summation of the weighted influence that each input has on the unsafe behaviour of a construction worker might ultimately lead them to commit unsafe acts while they work.

Step 2: Calculation of the expected USBS

The dataset from Part 2 of the questionnaire (refer Section 3.5.3.2) was used to quantify the USBS of each construction worker. According to "Educational Recourses" (2008), unsafe acts always have the potential to cause injury or death despite the nature of the act or the excuse or justification used to commit them. Therefore, it assumed that each unsafe act considered is equally potential of causing an accident, and thus, the USBS was modelled as a function of fifteen unsafe acts as illustrated in Figure 3-7.

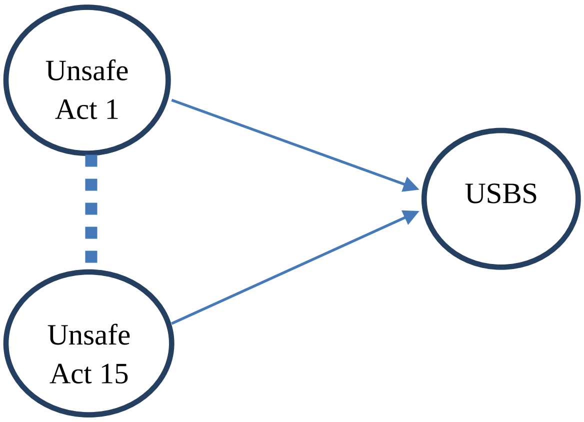

Figure 3-7: Calculation of expected USBS

Thus, the total USBS was obtained as the sum of the scores of fifteen unsafe acts using the following non-statistical formula (refer Equation 3-1).

$$\textbf{USBS} = \sum_{i=1}^{n}(S_{ai}) \qquad \textbf{(3-1)}$$

Where;

a_i = i^{th} unsafe act

S_{ai}= Score of i^{th} unsafe act, where $\forall S_i$: $1 \leq S_{ai} \leq 5$

n = Number of unsafe acts

The values calculated using Equation 3-1 was the expected output of the predictive model. The expected USBS was presented as a percentage using Equation 3-2.

$$\textbf{USBS\%} = \frac{\textbf{USBS}}{\textbf{Maximum attainable USBS}} \textbf{ X 100\%} \qquad \textbf{(3-2)}$$

Step 3: Network architecture of the predictive model

Literature identified two types of ANN as feedforward and feedback (refer Section 2.10). The multilayer feedforward ANNs are the most widely studied and used neural network model in practice (Muttil, & Chau, 2006; Vrajitoru, 2016). Feedforward ANNs can approximate complex non-linear functions due to their ability to learn through training and thus, ideally suitable for modelling relationships between a set of input variables and one or more output variables (Ripley, 1996). In other words, they are appropriate where input has to be mapped with the desired output for unknown functions. The research problem of the study resonates closely with this characteristic of the feedforward networks, and thus, it is clear that the feedforward ANN is the most suitable network type for the purpose.

Network design depends on three parameters: number of neurones in the input, hidden and output layers. The input layer is considered a distributor of the signals from the external world. Hidden layer(s) are regarded to be categorizers or feature detectors of such signals. The output layer is considered a collector of the features detected and producer of the response. However, the number of neurones in the input and output layers are pre-determined by the size of the input and output vectors respectively (Chew, De Silva, & Tan, 2004).

In this network, the number of nodes in these two layers were set as 14 and 1, where '14' corresponds to the fourteen influential factors of unsafe behaviour and '1' corresponds to the USBS of a worker. The size of the hidden layer was decided during the training of the network. Figure 3-8 denotes the ANN structure design.

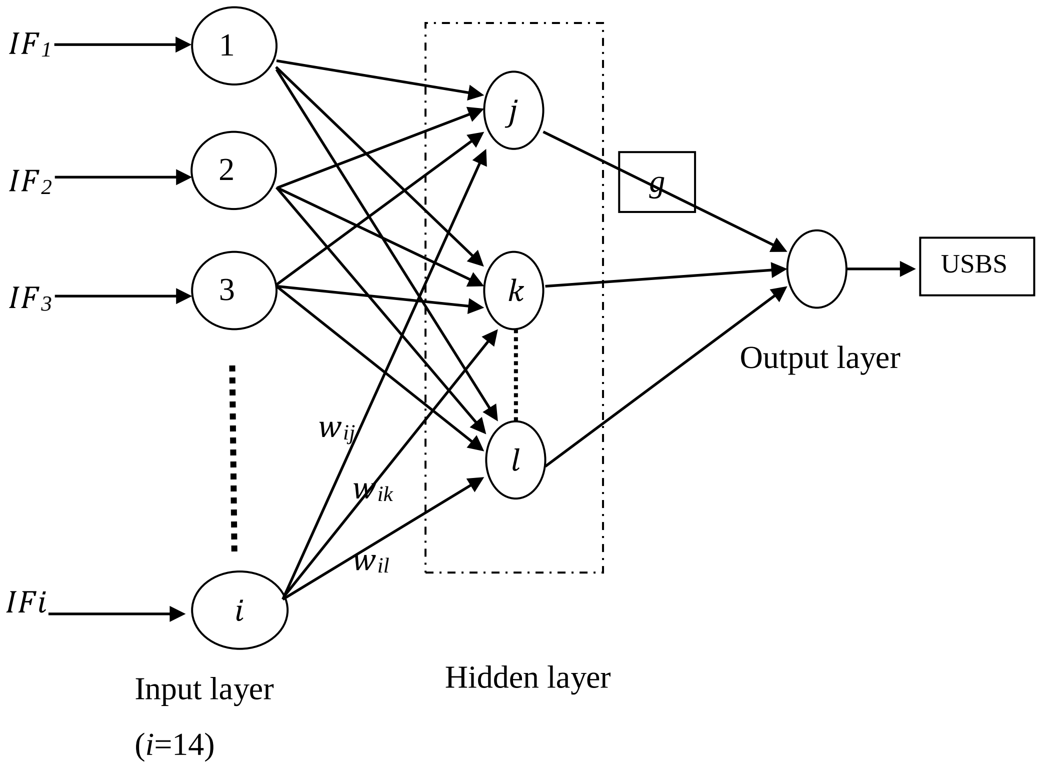

Figure 3-8: ANN structure

The ANN predictive model designed to obtain a USBS of a worker can be mathematically expressed as (Equation 3-3);

$$\mathbf{USBS_p} = \boldsymbol{g}\left[\sum_{\boldsymbol{i=1}}^{\boldsymbol{14}} \left(\boldsymbol{w_{ij}} . \boldsymbol{IF_i}\right)\right] \qquad \textbf{(3-3)}$$

Where,

$USBS_p$ = Network output of the p^{th} training case

IF_i = Input of the i^{th} influential factor (neuron)

w_{ij} = Random weight assigned between i^{th} and j^{th} neurons

g = Sigmoid transfer function

It must be noted that Equation (3-3) represents a linear function on the input space spanned by fourteen influential factors.

Step 4: Training the ANN predictive model

Many paradigms are available to train ANNs such as back-propagation algorithm, real-coded genetic algorithm, and a self-organizing map (Srinivasulu & Jain, 2006). However, backpropagation paradigm has been used widely for feedforward networks (Rumelhart et al., 1986). The use of a smooth, non-linear activation function is essential for use in a multi-layer network employing gradient-descent learning. According to Zhang et al. (1998), an activation function commonly used in backpropagation networks is the sigma (or sigmoid) function (see Section 2.8.3). Thus, a back-propagation algorithm with a 'sigmoid' transfer functions in the hidden layer neurones was used in the network training process. It consists two steps including forward pass and backward pass. In the forward pass, the output of a particular neurone with respect to the i^{th} training data set of the network is denoted by Equation 3-4.

$$\boldsymbol{S_j = g\left[\sum_{i=1}^{n}\left(w_{ij}.f_i\right)\right]} \qquad \textbf{(3-4)}$$

Where,

S_j = output of the j^{th} neuron

f_i = input of the i^{th} neuron

w_{ij} = random weight assigned between i^{th} and j^{th} neurons

g = activation function

In the backward pass of the network, the simulation process starts at the output layer by passing the error signal 'E_{net}' which is the difference between network output and the expected output as (refer Equation 3-5);

$$\mathbf{E_{net}} = \boldsymbol{\frac{1}{2n}\sum_{j=1}^{n}\left(USBS_j - Net_j\right)^2} \qquad \textbf{(3-5)}$$

Where;

n = the number of training samples

$USBS_j$= the expected output of the j^{th} training sample

Net_j= the corresponding network output

Input and output vectors for backpropagation need to be normalised properly to achieve the best performance of the network (Kim, 1998). If numeric data is not normalised, and the magnitudes of two predictors are far apart, then a change in the value of an ANN weight has a far more relative influence on the x-value with larger magnitudes. In essence, normalisation is done to have the same range of values for each of the inputs to the ANN model. Thus, data must be scaled into the range used by the input neurones in the ANN. This is typically the range of 0 to 1 (Mitchell, 1997). Thus, to normalise the data set, each data point was divided from the maximum attainable value of the variable which placed training dataset within the range 0 to 1. Out of the 284 training cases available from data collection, 277 cases were included in the training set. 7 cases were reserved for validating the network once it was trained.

Step 5: Demonstrating the ANN predictive model

The predictive model is developed linking influential factors for unsafe acts and its resultant level of unsafe behaviour using USBSs. Since ANN is known to be a black box (Heinert, 2008), the underlying relationship between these two is not demonstrated. Since the credibility of the model depends on its ability to explain its conclusions, the visualisation of the model was important to understand how unsafe behaviour of a worker is established. Sensitivity analysis is used to determine how much ‘‘sensitive’’ the model is to the changes in the values of the parameters of the model (Shojaeefard, Akbari, Tahani, & Farhani, 2013). Thus, a sensitivity analysis was carried out to explore the relationship.

The Mean Absolute Error (MAE) calculation, which is a useful measure widely used in model assessments (Chai & Draxler, 2014) was employed in analysing the sensitivity of the model to each influential factor. The expected output of each data point was calculated. Then, by using the developed model, the output connections of each neurone of the first layer (independent variables) were removed (refer Figure 3-9) and the network output to the set inputs was noted down.

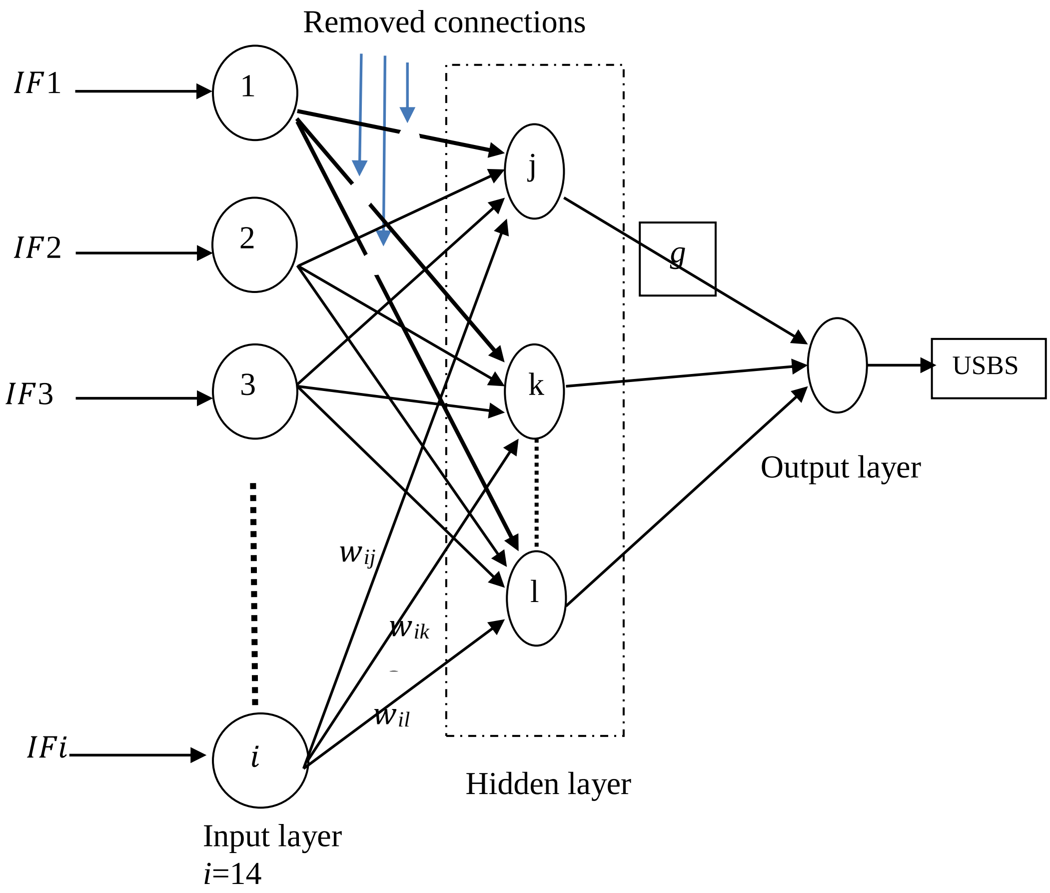

Figure 3-9: Sensitivity analysis of ANN predictive model

The process was repeated for all data points in the training set, 14 times each for every training case and using the information, MAE of each data point for the nullified independent variable was calculated using Equation 3-6.

$$\mathbf{MAE}=\frac{1}{n}\sum_{i=1}^{n}|Ti-Ci| \qquad \textbf{(3-6)}$$

Where; n= Number of data points

Ti= Target output of the *i*th data point

Ci = Calculated output of the *i*th data point

The calculated MAEs were used in demonstrating the architecture of the model.

Step 6: Validation of the ANN predictive model

The trained ANN model required to be validated in terms of genaralisability. The forecast error is simply the difference between actual and computed outputs, regardless of how the forecast was produced (Hyndman, 2006). If the trained ANN has achieved the expected performance level, the forecast error should be between the permitted range in training.

Accordingly, to validate the trained network, the information generated from 7 completed questionnaires, which were not used in training set, were utilised. The data were normalised accordingly and fed to the trained network to check whether the ANN has reached the expected performance level. The calculated output produced by the network for each data point was compared with the actual (expected) output of each data point to check whether the errors were in the permitted range which was ± 0.01 (refer Section 4.4.3.3).

3.6 Research validity

Content validation, replication, internal and external validation were the measures taken to validate this research study. Before the main survey, the questionnaire was tested by conducting a preliminary survey and relevant implications were identified which ensured the content validity. Further, the questionnaire was tested using Cronbach’s alpha to ensure the data collected was reliable certifying the replication. The large sample (400 respondents) and high response rate (71%) also improved the validity of research findings. Further, in the research analysis, the developed model was validated using 7 new data points (Cases) to ensure validity.

3.7 Summary

This chapter discussed the research methodology of the study. Firstly, the importance of adopting a framework (Creswell, 2009) for effective design of the research process was discussed. Accordingly, the methodological paradigm, research strategy and research method followed in the study were elaborated with reasoning. The appropriate methodological paradigm for the study was discussed leading to the justification of the adopting of positivism to the research. Furthermore, quantitative research strategy with a survey approach was selected for the study considering the nature of the research questions, and data to be collected and analysed.

The method undertaken to conduct the research was detailed in the section that followed. The research method was described under four phases, namely; background study, literature review and the pilot study, main survey and data analysis. The purpose and the nature of the background study, structure of the literature review and its findings, the conducting of the pilot study and the main survey, and a stepwise discussion of the data analysis methods utilised were detailed under these four phases in describing the unique process that was followed. Next chapter is allotted to discuss the data analysis and findings of the study.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

CHAPTER 4

4. DATA ANALYSIS AND FINDINGS

4.1 Introduction

The research methodology adopted in the research was described in Chapter 3. The purpose of this Chapter is to present the data analysis and findings of the research. Section 4.2 denotes the overall demographics of the sample. The results of the analysis and the corresponding findings are discussed in Section 4.3 under five subsections. Section 4.3.1 describes the findings on the unsafe acts exhibited by the sample. Reliability analysis of the survey data is presented under Section 4.3.2, accordingly justifying the suitability of the data sets for further analysis. Section 4.3.3 presents the ANN predictive model development and training. Analysis and findings on model validation and the demonstration are successively presented under Section 3.4.4 and Section 3.4.5 respectively.

4.2 The responsive sample

In the main survey, 400 questionnaires were distributed among construction workers of 20 C1 Building construction sites located in Colombo district to identify unsafe acts committed by construction workers and their influential factors. 302 questionnaires were returned to the researcher. After screening for completeness of the responses, 18 questionnaires were removed, and thus, 284 complete responses from the target sample were attained, resulting in a response rate of 71%. The sample consisted of workers employed in different job categories as illustrated in Table 4-1.

Table 4-1: Responsive sample

Job category	Number in the responsive sample	Percentage in the responsive sample
Carpenter	36	12.7%
Electrician	34	12.0%
Mason	79	27.8%
Plumber	21	7.4%
Welder	25	8.8%
Rigger	39	13.7%
Concrete worker	25	8.8%
Bar-bender	20	7.0%
Aluminium worker	5	1.8%

4.3 Reliability analysis of data

The completed questionnaires produced two datasets for data analysis as the data for calculation of the expected USBS (refer Section 3.5.4.3) and the data on influential factors. Dataset 1 included 15 items (variables) featuring unsafe acts committed by construction workers. Dataset 2 consisted of 14 items (variables) which were the influential factors of unsafe behaviour. The two datasets were analysed using Cronbach's alpha for reliability of the data in SPSS. Table 4-2 denotes the alpha values for each dataset.

Table 4-2: Results of reliability analysis

Dataset	Stats				Cronbach's alpha	No. of items
			Number	Percentage		
1	Cases	Valid	284	100.0	0.82	15
		Total	284	100.0		
2	Cases	Valid	284	100.0	0.795	14
		Total	284	100.0		

As presented in Table 4-2, the reliability of the scale scores of Dataset 1 (Unsafe acts) was 0.82 which is regarded as 'good reliability'; while the reliability of the scale scores of Dataset 2 (Influential factors) was 0.795 which is interpreted as 'acceptable reliability'. Thus, the reliability analysis results proved that the two datasets were sufficient to proceed with the data analysis.

4.4 Data analysis and discussion

4.4.1 Unsafe acts

The study used a Likert scale to collect data on unsafe acts (refer Section 3.5.3.2). In a Likert scale, the response categories have a rank order, and the intervals between values can be presumed equal (Blaikie. 2003; Hren et al., 2004; Santina & Perez, 2003). Likert scale items are created by calculating a composite score from Likert items; therefore, the composite score for Likert scales should be analysed at the interval measurement scale (Boone & Boone, 2012; Saha & Paul, 2016). The best measure of central tendency recommended for interval scale items is the mean (Clason & Dormody, 1994; Manikandan, 2011). Hence, Table 4-3 shows the mean rates of occurrence of the unsafe acts among the construction workers, sorted in the order of the frequency.

Table 4-3: Unsafe acts-Mean rating of occurrence

Unsafe Act	Description	Mean occurrence
1	Improper posture for tasks	3.11
2	Not wearing PPE	2.40
3	Working at improper speeds	2.39
4	Incorrect use of tools and equipment	2.24
5	Working in poor physical conditions	2.07
6	Throwing or dropping objects from high levels	2.06
7	Annoyance and horseplay in the workplace	1.96
8	Working without authority on the job	1.81
9	Removing safety guards from the workplace or equipment	1.75
10	Working with lack of concentration	1.66
11	Using defective equipment and tools	1.53
12	Working under the effects of alcohol/drugs	1.31
13	Leaving nails or other sharp objects protruding from surfaces	1.31
14	Servicing equipment which is in operation	1.25
15	Smoking, creating naked flame or sparks in areas where flammable materials are stored	1.23

According to the results, improper posture for tasks, not wearing PPE, and improper speeds for tasks have the highest mean ratings of occurrence. 48% of the respondents reported that they use improper posture for tasks all of the time at work and 21% of the sample did not wear PPE to work at all. 18.4% of the sample reported working at improper speeds most of the time.

Both improper posture and speed for tasks can lead to acute trauma such as cuts or fractures due to accidents in the workplace (Da Costa & Vieira, 2010, EU-OSHA, n.d., Fernandez, 1995). These two ergonomically wrong acts may be due to the lack of application of ergonomics in the construction industry in Sri Lanka. The limited knowledge of workers regarding ergonomics and related problems (Loo & Richardson, 2012) may also contribute to the high occurrence rate.

Not wearing PPE is the other most frequent unsafe act committed by the construction workers. This act is common among workers in the other industries as well (Ahmed & Azhar, 2015). The high frequency of occurrence of the unsafe act can most probably be due to the poor risk perception of the workers and discomfort associated with wearing PPE, especially in a tropical country like Sri Lanka.

Incorrect use of tools and equipment frequently during work was reported from 13.7% of the responsive sample. Further, 5% of the workers reported that they work in poor fitness most of the time while 10.8% reported to be throwing or dropping objects from high levels most of the time during work. Annoyance and horseplay in the workplace was common among 14% of the responsive sample. Responses also revealed that 3% of the responsive sample work without authority on the job, 3.9% remove safety guards from the workplace or equipment, and 5.7% work with without concentration most of the time.

The least common unsafe acts among the sample were smoking/creating naked flame or sparks in areas where flammable materials are stored, servicing equipment which was in operation, and leaving nails or other sharp objects protruding from surfaces. According to the responses, 82.7% of the sample never created naked flame around flammable material. During work, 79.4% always withheld from servicing equipment which is in operation, and 79.1% of the sample never left sharp objects protruding from surfaces.

The data collected were employed in calculating the expected USBS of construction workers (refer Section 3.5.4.3) of the responsive sample (refer Figure 4-1).

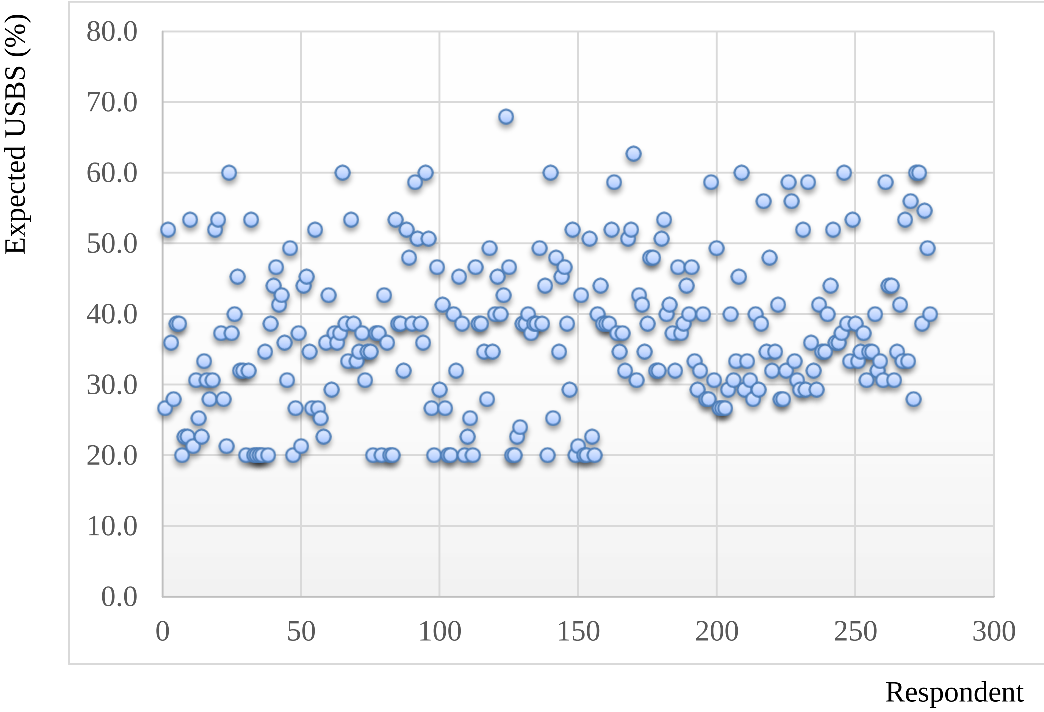

Figure 4-1: Expected USBS of the responsive sample

As shown in Figure 4-1, USBS of the construction workers in the responsive sample ranged from 20% to 68%. Workers who scored the lowest USBS (20%), indicating a safe work behaviour during work, accounted for 8.6% of the responsive sample. On the other hand, 15.2% of the responsive sample exhibited USBSs over 50%, displaying high unsafe behaviour in general. As elaborately discussed in Section 4.4.3.1, the expected USBS was utilised in developing the ANN predictive model.

4.4.2 Influential factors

Fifteen distinctive influential factors were identified literature which were then validated to Sri Lankan construction industry in a pilot study. All the experts agreed that the influential factors identified in the literature were common to Sri Lankan context as well except for one. Gender had been identified in the literature as an influential factor of unsafe behaviour (Choudhry & Fang, 2008; Fang et al., 2006). However, the pilot study findings led to exclude the influential factor from the validated list as Sri Lankan construction industry is male dominated. Thus, the original list of factors was moderated accordingly. The moderated list included 14 influential factors under three constitutes (refer Table 4-4).

Table 4-4: Factors influencing unsafe behaviour of construction workers in Sri Lanka

Person	**Process**	**Place**
Age	Hazardous operation	Safety procedures & rules
Experience	Unsafe conditions	Management commitment to safety
Alcohol/drug abuse	Hazardous equipment	Employee involvement in safety
Education		Safety communication
Attitude towards safety		
Psychological distress		
Income		

As per the survey data, 13.7% of the responsive sample were workers older than 50 years of age. Workers who were younger than 25 years of age accounted for 14.8% of the responsive sample. The mean age of the workers in the sample was 36.3 years. When years of experience were considered, 20.6% of the responsive sample had work experience more than 20 years. Similarly, 24.6% had work experience less than 5 years. The average work experience of a worker of the responsive sample was 13.2 years. 7.9% of the responsive sample reported to have severe case of alcohol/drug abuse while 51.3% had no such issues at all.

The education levels of the responsive sample varied from no formal education to the General Certificate of Education (GCE) Advanced Level/National Vocational Qualification (NVQ) level 3. 5.8% of the responsive sample had no formal education while 13% had only a primary education. 21% of the responsive sample reported to have an education up to GCE Advanced Level/NVQ level 3.

Out of the respondents, only one expressed strongly negative attitudes towards safety at work. 53.4% of respondent displayed strong positive attitudes towards safety while 22% of the responsive sample remained neutral about the factor. Similarly, one respondent displayed symptoms of severe psychological distress while 47.6% of the responsive sample reported to have no psychological distress. When income was questioned, 43.3% of the respondent reported that their income was unsatisfactory. Only a 3.2% of the responsive sample was satisfied about their income.

50% of the workers in the responsive sample engaged in hazardous operations during work while 61% reported to encounter unsafe conditions on site. 40.4% of the respondents said they use hazardous equipment during work.

When the safety procedures and rules were considered, 84.5% of the responsive sample agreed that up-to-date procedures and rules for safety were available in their organisations, and that they are trained in those. 42.6% of the responsive sample had observed good management commitment to safety while 41.1% said the workers in their organisations actively involved in safety. According to the responses of the sample, 43.3% were satisfied with the safety communication of their organizations while 7.2% of the responsive sample reported it to be dissatisfactory.

Further, each of these factors displayed varying degrees of influence on unsafe behaviour of workers. Accordingly, Section 4.4.3.2 discusses how these factors are linked with the USBS of construction works in Sri Lanka.

4.4.3 ANN predictive model

4.4.3.1. Model development and training

The ANN model was developed using Neuroph Studio, considering the influential factors of unsafe behaviour as the independent variables and the USBS as the dependent variable. As discussed in Section 3.5.4; the data must be scaled into the range used by the input neurones in the ANN, which typically is the range of 0 to 1 (Mitchell, 1997). Thus, to normalise the training dataset, each data point was divided from the maximum attainable value of the variable which placed both the training dataset within the range 0 to 1. Out of the 284 training cases available from data collection, 277 cases were included in the training set. Thus, training dataset was $[I]_{15x277}$ matrix consisting values between 0 and 1 (refer Appendix 5) as per the theory developed (refer Section 3.5.4). The normalised data were used to create the training set of the ANN in the Neuroph library. Supervised learning was selected as the learning type for the network since the researcher is incorporated in the process as an external teacher (Fritzke, 1994), setting each expected output to input signals.

Widely accepted trial and error method was adapted to design the network (i.e. change the number of hidden layers and nodes) of the predictive model. Thus, three network architectures had to be developed and trained to obtain the optimum network structure for the model. For each created network, 14 input neurones and 1 output neurone were set as they represent the input and output data of the model. Additionally, bias nodes were added to increase the flexibility of the model to fit the data. Hidden layers were added in each network and the number of nodes was changed until the optimum network obtained. For every network, the activation function of the nodes was set to be sigmoid in the backpropagation training algorithm.

During the network training using Neuroph Studio, three learning parameters including max error, learning rate, and momentum were required to set. Learning rate was the constant in the algorithm of the ANN that affected the speed of training. Though the network would learn faster if the learning rate is high, if there is significant variability in the input, the network will not learn efficiently at a higher learning rate (Domingos, 2012). Thus, it was set at a low range to obtain smooth iterations in the training cycles.

A backpropagation network might settle to local minima by sliding down the error surface into a set of weights that does not solve the problem it is trained on. The Momentum allows the network to potentially skip through local minima (Rich, Night, & Nair, 2009). The training parameters were altered during the training until the optimum network is achieved. The stopping criterion (max error) for the optimum network was ± 0.01 (1%) while the learning rate was 0.2 and momentum was 0.7. Table 4-5 shows the ANN training results.

Table 4-5: ANN training results

Network	**Inputs**	**Outputs**	**Hidden layers**	**Learning rate**	**Momentum**	**Iterations**	**Total network error**
1	14	1	2 (10,15)	0.01	0.2	17760	0.002
2	14	1	2 (7,8)	0.2	0.7	11576	0.007
3	14	1	1 (20)	0.2	0.7	16749	0.001

As shown in Table 4-5, the third network with total network error of 0.001, 14 neurons in the input layer, 20 neurons in the hidden layer and 1 neuron in the output layer yield the lowest total network error within the set max error.

When the lowest total network error value was reached within the set max error, the training became complete. Thus, the third network was considered as the optimum network for the predictive model.

Shown in Figure 4-2 is the total network error graph of the optimum network. Figure 4-3 illustrates structure of the optimum network.

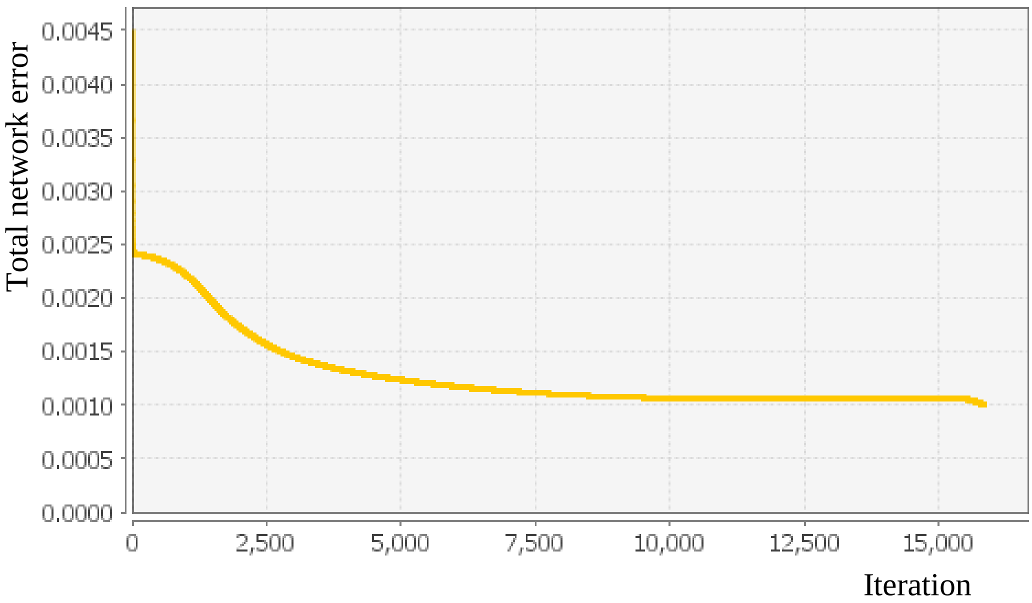

Figure 4-2: Total network error graph of the optimum network

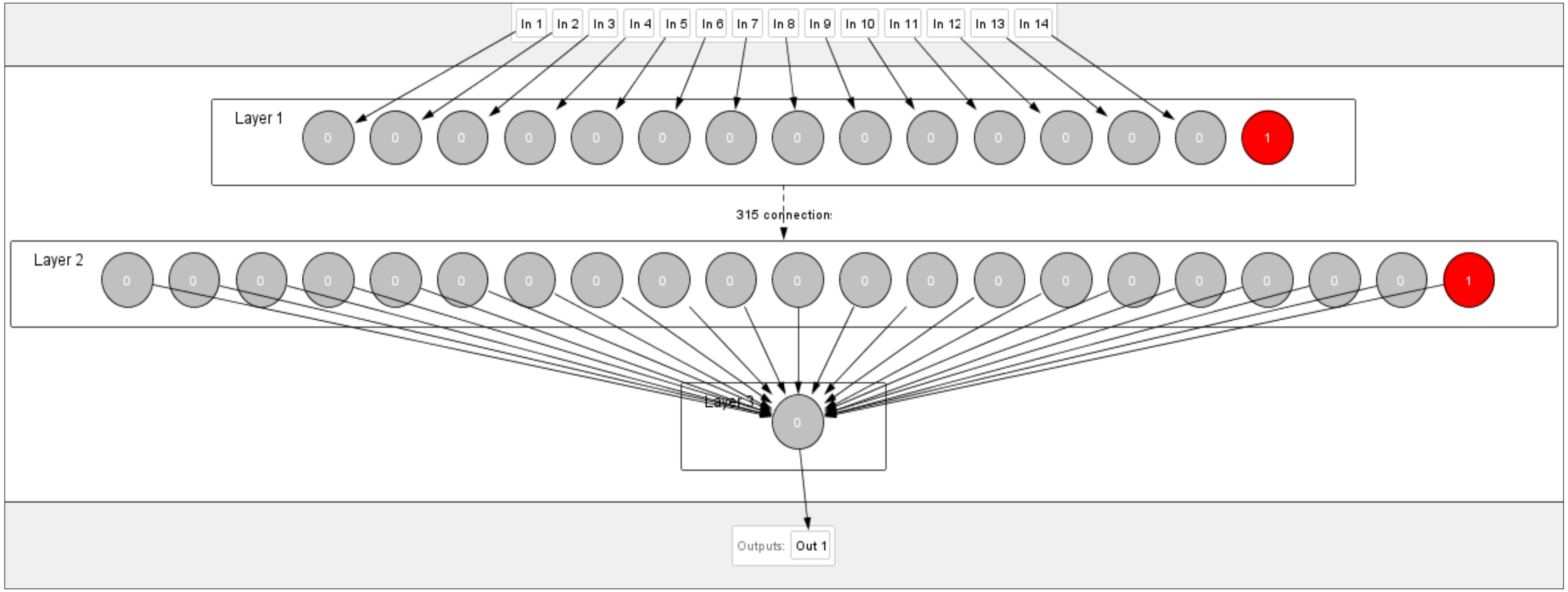

Figure 4-3: Structure of the optimum network of ANN predictive model

4.4.3.2. Demonstrating the model

The trained model was then subjected to a demonstration of its architecture to identify how the influential factors drive USBS of construction workers. Analysis was done according to the sensitivity analysis method discussed in Section 3.5.4. Table 4-6 ranks the influential factors of unsafe behaviour according to the sensitivity of the model to each. The architecture of the ANN predictive model, established based on the sensitivity analysis results, is illustrated in Figure 4-4.

Table 4-6: Results of the sensitivity analysis

Influential Factor	**MAE**	**Rank**
Education	0.121	1
Management commitment	0.107	2
Unsafe conditions	0.105	3
Hazardous operations	0.089	4
Income	0.087	5
Experience	0.085	6
Attitudes towards safety	0.077	7
Safety communication	0.075	8
Age	0.071	9
Alcohol/drug abuse	0.065	10
Psychological distress	0.064	11
Hazardous equipment	0.063	12
Safety procedures and rules	0.062	13
Employee involvement in safety	0.059	14

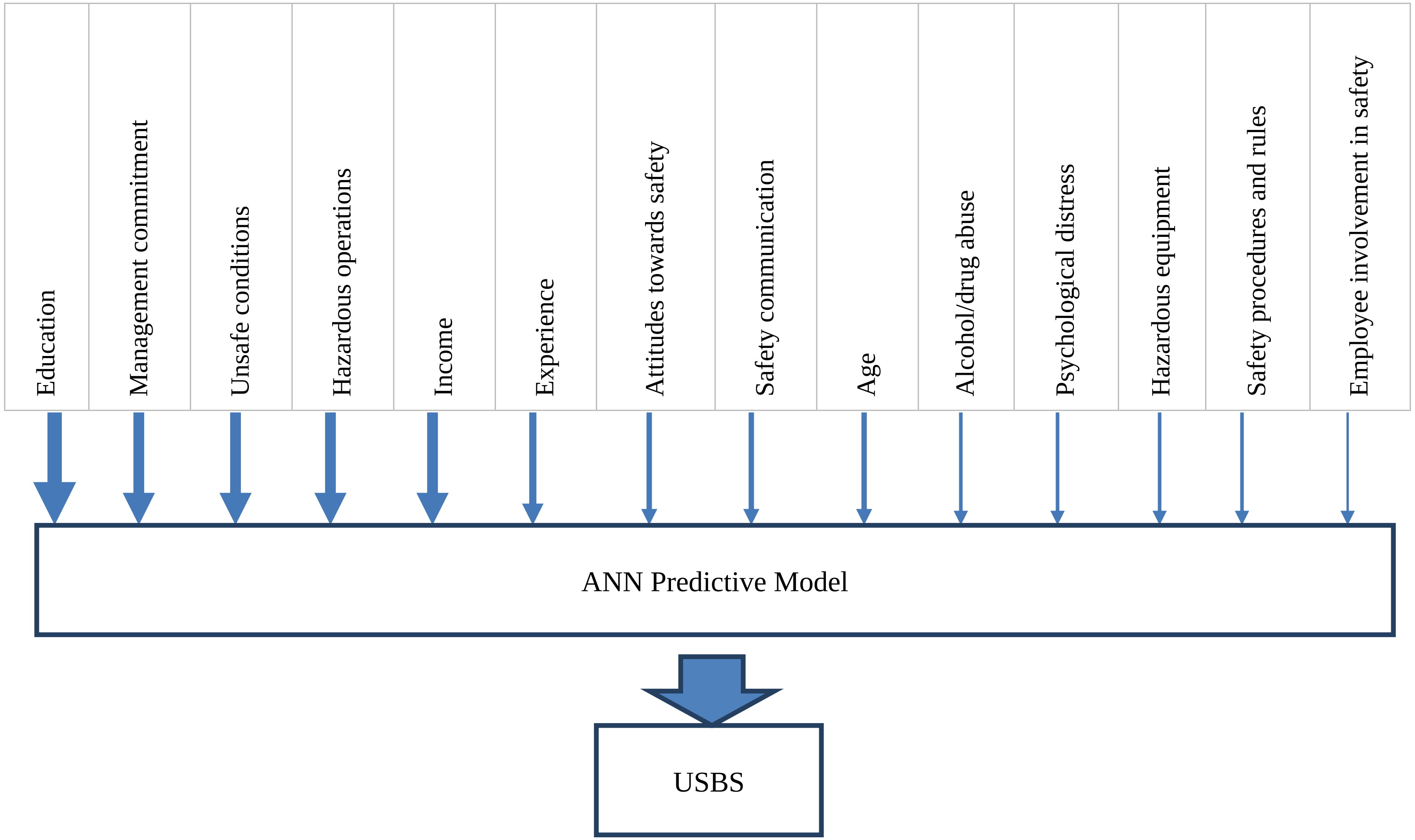

Figure 4-4: Architecture of the ANN predictive model

Education

As depicted in Figure 4-4, ‘education’ was the neurone to which the predictive model demonstrated the highest sensitivity. According to literature, there exists a significant correlation between unsafe acts and education level (Abbasi, Gholamnia, Alizadeh, & Rasoulzadeh, 2015; Alizadeh, & Moshashaei, 2015; Hinze, 1997; Postlethwaite, Robbins, Rickerson, & McKinniss, 2009). Pilot study findings also revealed that when the workers are educated, the occurrence of the purposeful unsafe acts is low. According to the expert E3, *educated employees see the importance of following safety guidelines in work*. Expert E1 revealed that their workforce consists mostly of junior school pass-outs and people with secondary education and people with secondary education are comply with safety practices than those with an education level of primary or lower. Thus, the research findings complement the literature and pilot study findings on the link between education and unsafe behaviour.

Management commitment to safety

The second most sensitive neurone in the model was ‘management commitment to safety’. Literature has persisted that management commitment to safety is vital if an organisation wants to promote safe behaviours among the workers (Choudhry et al., 2007). Pilot study findings also revealed a similar correlation. Expert E3 believed that what workers are more product oriented. They do not consider the repercussions of the process and tend to choose the easy way over the safe way of performing duties. Expert E2 added that the management has to be visibly engaged in safety so that it can positively influence the safe work practices. If managers are committed to safety, proper establishment and monitoring of safety systems can be ensured which will lead to safe work behaviours of the workers. Hence, the strong relationship among management commitment to safety found in the literature and the pilot study findings is established by the predictive model architecture.

Unsafe conditions

The neurone 'unsafe conditions' was ranked as the third most sensitive neuron according to the sensitivity analysis results. Unsafe conditions is the second most prominent cause of accidents after unsafe behaviour (Henrich, 1931). Hazard free-construction site is a must to ensure accident-free environment and can promote safe work practices among workers (Choudhry & Fang, 2008).

Pilot study findings also supported the strong correlation between unsafe conditions and unsafe behaviour of workers. Expert E2 clarified that *site which is free of unsafe conditions display the organisation's commitment to safety, hence, the worker automatically adheres to safe work practices*. Expert E4 agreed to this clarification by pointing out unsafe conditions provide an excellent excuse for workers' unsafe behaviour. Thus, experts were in agreement that employees tend to take safety seriously when it is displayed in the work environment.

Hazardous operations

Neurone representing 'hazardous operations' was ranked as the fourth most influential factor. The complexities of the construction industry and its processes make the construction sector one of the most hazardous industries that cause a high rate of accidents (Pungvongsanuraks et al., 2010). Experts also held a firm belief that due to complex operations there is room for unsafe acts. Expert E3 pointed out that *in a hazardous operation such as excavation or trenching, workers can subconsciously engage in unsafe acts*. According to expert E5, *in operations those include working at heights or use of heavy and mechanised equipment, a simple mistake can lead to fatal accidents*.

The experts agreed that hazardous operations could influence, in more of a latent manner, the unsafe behaviour of workers by creating opportunities, or rather excuses for them to engage in those.

Income

'Income' was ranked as the fifth neurone to which the model was sensitive. The literature review revealed that the low or poor income and economic conditions lead the worker towards engagement in unsafe behaviour (Goldenhar el al., 2003; Suraji et al., 2001). Generally income of a construction worker is low in Sri Lanka. Expert E2 agreed that poor income could be a stressor to workers. This statement was supported by expert E4 who stated that *safety becomes a secondary concern when one have money matters to think of*. Most of the experts have observed that workers who are the sole provider of their families take unnecessary risks at work than others. Especially, in a developing country like Sri Lanka, poverty is a major concern. Experts pointed out that when money becomes important than safety, workers choose the quicker ways over the safer ways to perform their duties.

Experience

The sixth most sensitive neurone of the model was 'experience'. Literature findings asserted that more experienced workers in the industry are less likely to behave in an unsafe manner while they work (Choudhry & Fang, 2008; Masood & Choudhry, 2012; Siu et al., 2003). Expert E2 stated that, *experience let the workers know what sort of danger they are dealing with and what would the consequences be*. Thus, workers with more years of experience in the industry would naturally accustomed to safe behaviours than those with less experience, as per expert E2.

Nevertheless, it is a continual learning process, and one's perception of risk can be changed or modified by subsequent experiences (Choudhry & Fang, 2008). Thereby, highly experienced workers might behave in an unsafe manner, not because they do not see the risk, but due to their changed perception of the severity of the risk. Thus, the moderate sensitivity of the model to the neurone representing 'experience' can be justified.

Attitudes towards safety

'Attitudes towards safety' was ranked as the seventh most sensitive neurone. In reviewing the literature, positive attitudes towards safety were proven to lead to safe behavioural patterns of construction workers (Langford et al., 2000). Pilot study findings also suggested the same. Expert E3 pointed out that *it can only be obvious for a worker with positive attitudes towards safety to behave in a safer manner at work.* As per expert E2, *when a person has a positive outlook on safety it becomes a priority regardless the environment he blends into.*

However, positive attitudes influence the worker to behave in a safer manner as long as he decides to act on them. Thus, if there is no constructive alignment between how worker thinks and how he behaves, attitudes become futile in influencing behaviour. This may be the reason for the moderate sensitivity displayed by the predictive model to the neurone, 'attitudes towards safety'.

Safety communication

Based on the sensitivity analysis results, neurone representing 'safety communication' was ranked eighth. Literature assigns a paramount importance on communication as an influential factor in safe work practices (Cheyne et al., 1998; Hofmann & Stetzer, 1998; Shin et al., 2014). In the pilot study, experts were in agreement that communication about safety can influence the workers to avoid unsafe acts as long as the communication is two-way. Expert E4 pointed out that, *when safety concerns of the workers are reported, and they are addressed without delay, it becomes a motivation for the employees.* Expert E1 suggested that *making accident records available for the workers' reference could give them an idea of how accident-prone the industry is, and thereby motivate them to behave in a safer manner at work.*

The most commonly used methods for internal communication include presentations to senior management, staff and safety committees, team meetings, emails, videos, notice boards, newsletters, poster displays and signage (Vecchio-Sadus, 2007).

However, when Sri Lankan context is considered, most of these communication methods are used for the benefit of management and executive staff. Methods such as signage, posters and notice boards are usually allocated for the labourers' reference.

Thus, though safety communication does take place in the organisation, the extent to which the safety information is communicated to the worker level is questionable. The experts pointed out that safety should be an open topic in the organisation and so that people will adhere to safe work behaviour, which is usually not the case in Sri Lankan context. This may be the reason for the moderate sensitivity of the model to the neurone, 'safety communication'.

Age

The neurone representing 'age' was ranked at the ninth place according to model's sensitivity analysis. Substantial influence has been determined for age as an influential factor in unsafe behaviour in the literature (Hinze, 1997). In contrast, Yin (2016) found that, despite their high awareness of safety issues on site, older workers still exhibited unsatisfactory safety behaviour most likely due to their declined physical capabilities.

Experts have observed that the workers who are older in age are more cautious about work safety than youngsters in the industry, but according to Expert E1, *as the workers grow old, their confidence also grow. Overconfidence can lead to alter their perception of risk and make them take an unnecessary risk at work.* Hence, the moderate sensitivity of the model to the neurone 'age' can be explained due to these contrasting viewpoints.

Alcohol/drug abuse

Alcohol/drug abuse has been identified as an influential factor in unsafe behaviour throughout the literature (Henderson et al., 1996; Laad et al., 2013; Oswald et al., 2013). The pilot study finding also suggests the same. According to expert E4, *alcohol/drug abuse can alter a person's risk perception*. Expert E5 brought forth that *alcohol; especially drugs influence the worker's perception of what's safe, creating an illusion by altering the reality, leading them to engage in unsafe behaviour more often*.

However, the sensitivity shown by the predictive model to the neurone representing the factor was relatively low. This result may be due to the fact that the study did not assess the influence of alcohol/drug abuse on site as an influential factor. 'Working under the effect of alcohol/drug' was directly considered as an unsafe act. The findings indicate that as long as the worker reports to work sober, the influence of alcohol/drug abuse on unsafe behaviour is low.

Psychological distress

According to literature, psychological distress is positively associated with the unsafe behaviour of workers (Dunbar, 1993; Hofmann & Stetzer, 1996). Funk, Drew, and Knapp (2012) found psychological distress to have far-reaching social impacts. In the pilot study, common symptoms of psychological distress were introduced to the experts before obtaining their views on the topic. Expert E5 has observed that workers who are aggressive in nature face accidents more frequently than the others.

Expert E3 viewed that mood swings and anxiety can alter a person's focus from the task they are engaged in, threatening the safety of the person. However, comparatively low sensitivity of the model was evident for the neurone 'psychological distress'. According to the responses, 48% of the sample was reported to have no psychological distress, and only a 0.36% (one respondent) showed the symptoms of severe distress.

Hazardous equipment

Literature identified hazardous equipment used on construction sites to be a trigger of unsafe acts (Wachter & Yorio, 2014), pointing out that physical injury hazards are often caused by equipment used such as power access equipment, ladders, plant and machinery for excavation and processes such as manual handling, and roof work (Hamid et al., 2003).

This was confirmed in the pilot study as well. Expert E3 agreed to the literature findings by explaining that *improper use of equipment, hazardous or otherwise, is itself an unsafe act, and often seen among construction workers*. According to him, workers usually use the equipment as they please, ignoring the potential of accident it may bring.

Experts also pointed out that use of portable power tools and mechanised equipment can also influence unsafe behaviour. Expert E2 explained that *it is the worst of cases when the power tools lead to accidents because it involves losing of limbs and body parts at the slightest mistake*. According to literature findings and the pilot study findings, use of hazardous equipment on site has a positive relationship with the unsafe behaviour of a worker.

However, the model displayed relatively low sensitivity to the neurone. This suggests that the use of hazardous equipment on site might not always influence to unsafe behaviour. As long as the worker is knowledgeable, have sufficient training and patience to use the equipment properly, unsafe acts and accidents can be avoided.

Safety procedures and rules

Low sensitivity of the model to the neurone 'safety procedures and rules' was evident in the analysis. Literature affirmed that procedures and rules for safety, in other words, safety monitoring systems must be there to monitor employee behaviour towards safety. If these systems are well designed to capture every error and rectify them, employees automatically adhere to these systems (Mohamed, 2003; Pidgeon & O'Leary, 2000; Sawacha et al., 1999).

The pilot study confirmed the positive effect of having procedures & rules for safety on workers' behaviours. According to expert E4, if these systems are well designed to capture every error, employees automatically adhere to the rules of safety. This idea was further approved by expert E5, stating that stronger the system, stronger the priority is given to it by the workers. So, it is only natural that workers tend to behave safer while at work when there are proper rules and procedures for safety.

In summary, the experts agreed that having well designed, documented, practical and up-to-date rules and procedures for safety enforces regulatory requirements, and workers will automatically follow those as an act of compliance.

However, the health and safety policies those govern safety procedures and rules of many major companies in Sri Lanka are not accurate and up to the standard, and are not communicated to the workers (Darshana, 2017). This may be the reason for the low sensitivity of the model to the neurone.

Employee involvement in safety

The model demonstrated the lowest sensitivity to the neurone representing 'employee involvement in safety'. Research has supported the positive relationship of employee involvement in safety with safe work ethics (Cox & Cheyne, 2000; Dedobbeleer & Beland, 1991; Lee, 1998; RoSPA, 2012; Rundmo, 1994; Shannon et al., 1996; Vredenburgh, 2002).

Though experts agreed with the literature findings, they also revealed that workers at the lower level of the chain think of safety as management's responsibility and not theirs. Expert E5 persisted that it is important to change this attitude and get the workers more involved in safety mechanisms of the organisation. Expert E1 pointed out that *because of the major case of under-reporting of construction accidents, people have no accurate idea of how accident-prone the industry is, and the main reason behind this is the under-involvement of employees in safety*.

The pilot study findings suggest that, when the Sri Lankan construction industry is concerned, employee involvement in safety is low, and seeing and experiencing other employees get actively involved in safety does not act as an external stimulus for an individual to behave in a safer manner at work. This may be the reason for the low sensitivity of the model to the neurone.

Thus, the sensitivity analysis results led to visualise the weightages assigned to each influential factor by the model and thereby to establish the structure of the ANN predictive model (refer Figure 4-4). Next section discusses the results of the validation test carried out to examine the generalisability of the model.

4.4.3.3. Model validation

Validation is an essential step in the acceptance of any model. It helps to establish the confidence in the technique (Still, 2000). In computer modelling, validation is defined as the systematic comparison of model predictions with reliable information (Fruin, 1971). Thus, validation in this study was the application of the attuned model and comparison of the results (calculated output) against observed data (desired output).

Data on unsafe behaviour and influential factors of unsafe behaviour were collected before the modelling. A set of randomly selected seven data points (referred to as 'cases' from here onwards), which were not used in developing the model, were employed as the validation set of the developed model.

Table 4-7 presents the reported unsafe behaviour of cases in the validation set. Frequencies of the cases' engagement in unsafe acts are indicated by numerals 1 to 5 as described in Section 3.5.3.2.

Table 4-7: Reported unsafe behaviour of the validation set

Validation Case	**Unsafe Act**														
	Working with lack of concentration	Working in poor fitness (physical conditions)	Throwing or dropping objects (materials and tools) from high levels	Working under the effect of alcohol/drugs	Smoking/creating naked flame in areas where flammable materials are stored	Annoyance and horseplay in the workplace	Working without authority on the job	Leaving nails or other sharp objects protruding from surfaces	Working at improper speeds	Using improper posture for tasks	Incorrect use of tools and equipment	Using defective equipment and tools	Not wearing PPE	Removing safety guards& features from the workplace	Service/maintain equipment & tools which is in operation
Case 1	1	2	1	1	1	1	2	1	2	4	2	1	1	1	1
Case 2	2	2	3	1	1	3	1	1	2	3	2	1	1	1	1
Case 3	1	2	1	2	1	1	2	1	2	2	2	1	2	1	1
Case 4	1	2	1	1	1	1	1	1	2	1	1	1	4	2	1
Case 5	1	1	2	1	1	2	1	1	3	4	1	1	1	1	1
Case 6	3	2	3	2	2	4	1	3	4	5	3	2	4	2	1
Case 7	2	1	2	1	1	3	1	1	3	5	2	1	1	1	1

As shown in Table 4-7, Case 6 reported the highest USBS (54.67%) of the set. The frequently committed unsafe acts by the respondent were using improper posture for tasks, annoyance and horseplay in the workplace, working at improper speeds, and not wearing PPE. The only unsafe acts he refrained from during work were working without authority on the job and servicing equipment and tools which were in operation.

Second most unsafe behaviour was reported to have a USBS of 34.67% in Case 7. Same as in Case 6, the most common unsafe act committed in Case 7 was using improper posture for tasks. Case 2 reported the third most unsafe behaviour with a USBS of 33.33%. Throwing or dropping objects from high levels, annoyance and horseplay in the workplace, and using improper posture for tasks were the unsafe acts mostly committed by the respondent. Case 1, Case 3 and Case 5 reported a USBS 29.33% each, and the frequent unsafe act in all three cases was using improper posture for tasks.

The lowest USBS of the validation set was reported from Case 4. The worker refrained from most of the unsafe acts on site during work. The most frequent unsafe act reported in Case 4 was not wearing PPE. The USBS of Case 4 was 28%, which was comparatively low and implied a safe work behaviour on site. The data on influential factors of the each case were also collected and fed to the trained network in order to compare the observed and predicted results.

Figure 4-5 depicts the network outputs (predicted USBS) for the validation set.

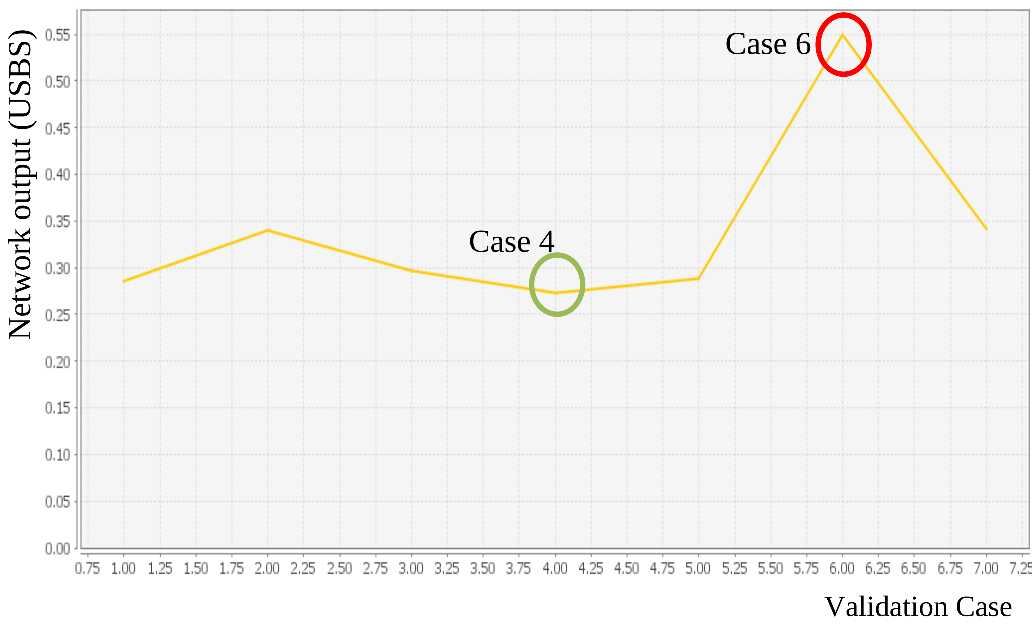

Figure 4-5: Network outputs for model validation set

The errors between the expected outputs of the Cases and the network outputs were compared to check the generalisability of the model. Table 4-8 shows the model validation results.

Table 4-8: Predictive model validation results

Input	**Network USBS**		**Expected USBS**		**Error**	
	Score	**Percentage**	**Score (Eq 3-1)**	**Percentage (Eq 3-2)**	**Score**	**Percentage**
Case 1	0.286	28.6%	0.293	29.3%	0.007	0.7%
Case 2	0.341	34.1%	0.333	33.3%	-0.008	0.8%
Case 3	0.296	29.6%	0.293	29.3%	-0.003	0.3%
Case 4	0.273	27.3%	0.280	28.0%	0.007	0.7%
Case 5	0.288	28.8%	0.293	29.3%	0.005	0.5%
Case 6	0.549	54.9%	0.547	54.7%	-0.002	0.2%
Case 7	0.342	34.2%	0.347	34.7%	0.005	0.5%

As shown in Table 4-8, the error of each case was in the range of ± 0.01 (1%). Since these error values were within the maximum error, which was the initially established value; the model can be considered as accurate to perform.

4.5 Discussion

Results in Table 4-8 show that the unsafe behaviour of above cases are at a higher level. This indicates that the construction industry should pay immediate attention to improve the performance of 14 influential factors (refer Table 4-4) in order to boost the BBS at site level. It also indicates that the likelihood for occurring an unsafe act is at a higher level, so that the identified unsafe acts among the construction workers on sites (refer Figure 2-3) can be very much expected.

Further, when the network USBS of the seven validation cases were considered, Case 4 and Case 6 yielded the lowest and the highest USBS respectively, complementing the expected USBS and there by the accuracy of the ANN predictive model. In viewing the values of influential factors of these two cases, contrasting differences as well as similarities were noted. Table 4-9 denotes the scale values of the influential factors of the two cases. As discussed in Section 3.5.3.2, values '1' to '5' assigned to influential factors represent the best (1) and the worst (5) case scenarios in relation to unsafe behaviour of the workers.

Table 4-9: Influential factor values of Case 4 & Case 6

Influential Factor	**Influential Factor Scale**	
	Case 4 (USBS=27.3%)	**Case 6 (USBS=54.9%)**
Age	2	5
Experience	1	5
Alcohol/Drug abuse	1	3
Education	2	5
Attitudes to safety	1	4
Psychological distress	1	3
Income	2	5
Hazardous operations	3	3
Unsafe conditions	2	5
Hazardous equipment	3	3
Safety procedures and rules	1	3
Management commitment	1	4
Employee involvement in safety	3	3
Safety communication	1	4

As shown in Table 4-9, the worker represented in Case 4 was predicted to have relatively safe behaviour on site (i.e. below 30%) while relatively high unsafe behaviour was predicted for the worker in Case 6 (i.e. above 50%). The worker in Case 4 belonged to the age group ‘2’ (i.e. 40-49 years) while the worker in Case belonged to age group ‘5’ (i.e. 18-24 years).

When work experience was considered, in contrast to the poor work experience record of Case 6, Case 4 depicted sound work experience record. Similarly, Case 4 has displayed low alcohol/drug abuse, higher education level, positive attitudes to safety, no psychological distress, and higher income in contrast to Case 6.

As far as the organisational safety cultures and the immediate work environments were considered, fewer unsafe conditions, strong safety procedures and rules, better management commitment to safety, and efficient safety communication mechanisms were reported in in Case 4. Engagement in hazardous operations, use of hazardous equipment at work, and employee involvement in safety were reported to have alike context in Case 4 and Case 6.

According to the sensitivity analysis of the predictive model to its inputs (influential factors), education level of the worker, management commitment to safety and the unsafe conditions on site are the most influential to unsafe behaviour of a worker. Those high influential factors are maintain at a good level in case 4 where in case 6, they were comparatively poor. Thus, it indicates that the organization should pay greater attention to enhance above influential factors in order to reduce unsafe behaviour of its workers.

On the other hand, use of hazardous equipment, availability of safety procedures and rules, and employee involvement in safety have little influence on unsafe behaviour according to the sensitivity analysis. Supporting this, the performance of above factors in Case 4 and Case 6 were irregular. Both the cases reported to have moderate employee involvement in safety in their respective organisations. Also, use of hazardous equipment were also at a moderate level in both the cases.

While safety procedures and rules in Case 4 was satisfactory, Case 6 reported it to be poor. Thus, the influence of these factors on unsafe behaviour of the workers are evidently low. Therefore, it is important to pay immediate attention to the sensitive factors than to those which are less sensitive, as the resultant improvement on BBS may be low.

When comparing the USBS and the influential factors of two extreme cases discussed, it is apparent that while it is difficult to pinpoint the exact relationship of each of the influential factors with the unsafe behaviour of a worker, the sensitivity analysis results are accurate. Factors such as sound education level, strong management commitment to safety, and minimum unsafe conditions on sites can reduce the unsafe behaviour of a worker.

4.6 Summary

The study results and a discussion of the findings of data collected were presented in this chapter. The findings of the pilot study and the main survey were discussed in detail. An introduction to the responsive sample was given prior presenting the key findings. The responsive sample consisted of 284 C1 building construction workers representing 9 job categories. The findings were described as correlations to the study variables and presented as tabulations and visuals, followed by elaborative discussions.

Cronbach's (1951) alpha test revealed the collected data to be reliable to proceed with the analysis. Among the identified unsafe acts, improper posture for tasks, not wearing PPE, and working at improper speeds became the most frequently committed acts by the construction workers during work. A step-by-step illustration of ANN predictive model development and training were presented in the subsequent sections of the chapter. To demonstrate the architecture of the model, a sensitivity analysis of the model was carried out. It was revealed that education is the most influential factor of USBS, followed by management commitment to safety, and unsafe conditions on site, while employee involvement in safety was the least influential.

Moreover, the sensitivity of the model to each influential factor was also compared against the literature and pilot study findings. The last section of the chapter demonstrated the generalisability of the developed ANN predictive model by applying the model to 7 new cases (validation set). Application of the model to new data revealed that the unsafe behaviour of the workers at site level is generally high in the Sri Lankan context, and there is a greater probability of occurrence of the unsafe acts on sites. According to the validation results, the developed ANN predictive model could predict USBS of a construction worker with a maximum error of ± 0.01 (1%), and thus, displayed high generalisability. This chapter marks the achievement of the final objective of the study and the research aim. The conclusions of the overall study are presented in Chapter 5.

CHAPTER 5

CONCLUSIONS

CHAPTER 5

5. CONCLUSIONS

5.1 Introduction

The previous chapter presented research analysis and findings of the empirical investigation. This chapter focuses on the summary of key findings to set up conclusions. Methodologically developed answers to the key research questions, which were raised based on the research problem, are presented in Section 5.2 as a summary of the key findings of the study. The summary of the key findings is then followed by research contributions to the knowledge and industry under Section 5.3 and Section 5.4 respectively. Study limitations are highlighted in Section 5.5. Finally, in Section 5.6, the chapter provides direction for future research emerging from this study.

5.2 Conclusions

The background study conducted based on existing knowledge confirmed the construction industry to be one of the most hazardous and accident-prone industries worldwide as well as in Sri Lanka. Two primary causes of construction accidents were identified as the unsafe behaviour of workers on sites and the unsafe conditions of the work environment. Furthermore, the unsafe behaviour of workers emerged as the most prominent cause of construction accidents. BBS was identified in the literature as a compelling solution to manage occupational safety through behaviour modification. The literature further clarified that studying the unsafe behaviour of workers and their influential factors are the first steps in implementing a BBS system in a workplace. Thus, the study was set out to investigate the unsafe behaviour of construction workers, with the aim of developing a model to predict the unsafe behaviour of construction workers. The background study led to three research questions, based on which the research objectives were formulated;

RQ1. What are the acts those characterise the unsafe behaviour of construction workers?

RQ2. What are the factors those influence the unsafe behaviour of construction workers?

RQ3. What is the impact of these influential factors on construction workers' unsafe behaviour?

In response to the research questions, three objectives were duly formulated.

i.) To identify the acts those characterise the unsafe behaviour of construction workers in Sri Lanka

ii.) To identify the factors influencing unsafe behaviour of construction workers in Sri Lanka

iii.) To develop a model to predict unsafe behaviour of construction workers in Sri Lanka

Hence, the significance of studying the unsafe behaviour of construction workers, the characterisation of unsafe behaviour, and its influential factors were examined to achieve the first two objectives. As the final step, a model was developed to predict the unsafe behaviour of construction workers, achieving the third objective of the research. Furthermore, a sensitivity analysis of the model was conducted to visualise the significance of each of the modelled influential factors towards the USBS of construction workers. The developed model was validated then for generalisability. This section concludes the key outcomes of the study derived from the analysed research findings resulted in the achievement of each objective.

Acts that characterise the unsafe behaviour of construction workers in Sri Lanka

Behaviour has been discussed in various perspectives like anthropology, psychology, personality science and so on throughout the literature. However, this research focused on data representing an individual's behaviour that is; data interpreted as reflecting the way a person acts. Since the research was limited to construction context and occupational safety, behaviours those are contextual to the said areas were taken into consideration. Acts those characterise the unsafe behaviour of construction workers were first derived from an extensive literature review. The outcomes of the literature were further validated to the Sri Lankan context in a pilot study whereby five construction industry experts participated. Thus, research established fifteen distinctive unsafe acts performed by the construction workers on sites;

- Working without authority on the job
- Annoyance and horseplay in the workplace
- Smoking, creating naked flame or sparks in areas where flammable materials are stored
- Leaving nails or other sharp objects protruding from surfaces
- Throwing or dropping objects from high levels
- Working under the effects of alcohol/drugs
- Working with lack of concentration
- Working in poor physical conditions
- Working at improper speeds
- Improper posture for tasks
- Incorrect use of tools and equipment
- Using defective equipment and tools
- Not wearing PPE
- Removing safety guards from the workplace or equipment
- Servicing equipment which is in operation

Research findings revealed that while all identified unsafe acts take place during construction work in Sri Lanka, the most common unsafe acts among the construction workers were using improper posture for tasks, ignoring to wear PPE, and using improper speeds for tasks. It was observed that poor management, communication and training are the main causes from which the unsafe acts stem. If workers do not understand why they need to use correct posture and speeds in tasks and wear PPE, they are more likely to refuse to comply with the need. Effective communication and consultation about the need for ergonomically sound posture and speed for tasks, and PPE at work, better training and reasonable adjustments to the workplace and PPE can reduce the occurrence of these unsafe acts.

Established on those unsafe acts, unsafe behaviour of the workers, with respect to a score (USBS), was derived based on the frequency of occurrence, assuming that each of the identified act is equally potential to cause accidents.

Influential factors of unsafe behaviour of construction workers in Sri Lanka

Influential factors of unsafe behaviour were identified through literature and later validated to the Sri Lankan context through the pilot study. The final list of influential factors was elaborated under three main constitutes as ‘person’, ‘process’ and ‘place’. Factors those related to the individual dynamics were listed under the ‘person’ constitute. Factors those belong to the work environment of the construction sites came under ‘process’ constitute, and the ‘place’ consisted of the factors those related to the organisational safety culture.

Under ‘person’ constitute, seven influential factors were finalised, namely;

- Age
- Experience
- Alcohol/drug abuse
- Education
- Attitude towards safety
- Psychological distress
- Income

‘Process’ constitute included three influential factors as;

- Hazardous operation
- Unsafe conditions
- Hazardous equipment

The influential factors those included in the 'place' constitute were;

- Safety procedures & rules
- Management commitment to safety
- Employee involvement in safety
- Safety communication

Survey findings confirmed that the above factors influence the unsafe behaviour of construction workers in Sri Lanka in varying degrees. A sensitivity analysis of the developed predictive model revealed that education was the most influential factor of USBS of Sri Lankan construction workers while employee involvement was the least influential.

ANN model to predict unsafe behaviour of construction workers in Sri Lanka

The third objective of this research was met by developing a model to predict the unsafe behaviour of construction workers. The developed theory was that the summation of the weighted influence each input has on the unsafe behaviour of a construction worker might ultimately lead them to commit unsafe acts while they work. Further, by examining the weights, the model assigned to the influential factors, the relationship between USBS and the influential factors can be established. Thus, theoretically, the model had to process the values of the influential factors which were the independent variables and produce a USBS which was the dependent variable. Since the underlying function is not known and non-linear, the modelling of unsafe behaviour was a complex problem.

Among modelling approaches for unknown complex problems used in the past, ANN is widely accepted and used for various applications with greater accuracy. Thus, ANN was selected to design and train the predictive model. ANN predictive models are developed using a large number of data set to embed the required knowledge using "supervised learning" to infer a function from labelled training data and predict outputs for future inputs.

The predictive model was developed and trained consisted of three layers as input, hidden and output. The input and output layers were predefined based on the influential factors and USBS. Since the influential factor values were the inputs of the model, 14 neurones were incorporated into the input layer. Output layer, which represented the USBS of a construction worker, was limited to one neurone. The number of neurones in the hidden layer of the trained network was 20.

Further, a sensitivity analysis of the model to its inputs was conducted to identify how the influential factors relate to the USBS. The results suggested that education, management's commitment to safety, and unsafe conditions are the influential factors which have the highest influence on USBS of construction workers in Sri Lanka, where all three factors are related to management practices.

Essentially education is an individual factor of which the worker has the control over, and the decision making power. However, once a worker joins a construction company, if arrangements can be made to educate the worker regarding occupational safety, through a programme that goes beyond training at the workplace, unsafe behaviour can be minimised.

Furthermore, management's commitment and the unsafe conditions on site are factors where management can directly interfere. When the management's commitment to safety is visible and stressing, workers behave in a safer manner at work. Thus, safety needs to be perceived as management's priority by the workers. Effective solutions to safety issues need to be provided as soon as they are raised so that the excuses to unsafe behaviour are minimised. Strong regulations and constant supervision are necessary to keep the work environment clear of hazards such as unguarded machinery, manholes, debris, reinforcement bars, and unguarded workspaces.

Once the model was trained, it was validated using seven new data points (Cases). The model could predict the USBS of construction workers with an error margin of ± 0.01. The findings of those seven cases imply that unsafe behaviour of construction workers is alarming in general. Most of the cases had around 30% of probability of displaying unsafe behaviour during work, while an extreme case displayed an unsafe behaviour over 50%. This implies that the influential factors of unsafe behaviour should be further managed and controlled in order to enhance the behavioural safety of workers.

The influential factors identified in the model, and the structure of the model can be applicable to any construction industry, yet the unsafe acts may need to be refined through external validation of the data. Importantly, the application of the discussed model would enable the organisations to decide on the level of unsafe behaviour of a construction worker based on the USBS. The lower the USBS, it is unlikely that the worker will behave in an unsafe manner on site and vice versa.

5.3 Contribution to knowledge

This research contributes to the knowledge by identifying the unsafe acts those characterise unsafe behaviour of construction workers and the influential factors of that unsafe behaviour. Factors which are critical for unsafe behaviour were also identified. Although research about construction safety, unsafe behaviour and computational modelling are available in abundance, there is no or little research that employs computational modelling to predict the unsafe behaviour of a construction worker. Thus, this study adds to the knowledge by combining the three fields to produce a predictive model of unsafe behaviour.

5.4 Contribution to the industry

This model motivates the industry practitioners to re-think construction safety. Different aspects of managing construction safety have been introduced by the factors mentioned in this model. For example, when considering construction safety, both individual workers and the organisation have roles to play. These roles need to be distinguished and established accordingly. The model also provides the industry with a solution for quantifying the unsafe behaviour of a worker and thereby deciding upon his safety need. Training programmes can be accordingly designed to establish a safe work environment within the organisation. In addition to the model, research produced a list of influential factors of unsafe behaviour sorted according to their impact on the said. This information can be utilised to devise behaviour based programmes those will provide the organisations with a well-disciplined workforce in the long run.

5.5 Research limitations

The projects from which the respondents were chosen for the study, were selected based on the CIDA grading and construction speciality. Hence, the respondents were randomly selected 400 workers in 20 building construction companies in Colombo metropolis. Though it facilitated the data collection and controlling diversity in the process, it limited the generalisability of the findings. As this research targeted to predict the unsafe behaviour of construction workers of C1 building construction workers, the research findings can be generalised to the mentioned population with confidence.

The researcher incorporated validated questionnaires wherever possible in devising the data collected instrument. However, the subjective measurement could not be avoided in certain questions such as in enquiring about the attitudes towards safety.

The findings rely on cross-sectional data rather than longitudinal data. This may not reflect the changing nature of unsafe behaviour and influential factors over time. The cross-sectional data can be affected by the respondent’s predisposition of any events that have happened in the past or by the mental position at the time of participating in the survey.

5.6 Future research directions

- **A study on unsafe behaviour of other specialities of construction**

This study was limited to C1 building construction workers and hence can only be generalisable to that category. The unsafe acts of workers and influential factors of unsafe behaviour might vary with the construction speciality. Thus, a study can be undertaken to cover other specialities of construction within the same research frame.

- **A study on behaviour based safety interventions for construction workers**

This research provides a basis for quantifying unsafe behaviour. A study can be undertaken to utilise the quantified unsafe behaviour to be incorporated in behaviour based safety models for construction workers.

- **A study on factors affecting unsafe behaviour of foreign workers in the construction industry in Sri Lanka**

As the entire sample of the study consisted of Sri Lankans, any possible implications of Nationality of the workers were overlooked. Thus, another research can be conducted to investigate the factors affecting foreign workers involved in Sri Lankan construction projects.

- **Modelling influential factors of applications in occupational health of the construction workers**

The study only focused on the occupational safety of the construction workers. Thus, the applicability of ANN can be explored to model influential factors affecting the occupational health of construction workers.

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APPENDICES

LIST OF APPENDICES

Appendix 1: Interview guidelines of the pilot study

Master of Philosophy

Introduction

Unsafe behaviour of a construction worker is governed by many factors, both individual and external. This research is conducted to investigate the influential factors of unsafe behaviour of the construction workers and the degree of influence of those factors. The questionnaire consists of three parts covering demographic data, unsafe acts committed by construction workers and influential factors of unsafe behaviour.

Statement of Confidentiality

The information generated from this questionnaire will be used only for the purpose of completing the research. All the responses of the interviewees will be kept confidential. Further, to maintain the confidentiality, the actual names of the organisations and the respondents will not be revealed under any circumstance.

Researcher:

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Part 1: Validation of Literature findings to Sri Lankan construction industry

Please indicate (with a tick) if the unsafe act listed below are relevant/common among the construction workers in Sri Lankan context.

Unsafe Act	Expert Response	
	Relevant	**Irrelevant**
Conduct		
Working without authority on the job		
Annoyance and horseplay in the workplace		
Smoking, creating naked flame or sparks in areas where flammable materials are stored		
Leaving nails or other sharp objects protruding from surfaces		
Throwing or dropping objects from high levels		
Working under the effects of alcohol/drugs		
Working with lack of concentration		
Working in poor physical conditions		
Ergonomics		
Working at improper speeds		
Improper posture for tasks		
Tools and Equipment		
Incorrect use of tools and equipment		
Using defective equipment and tools		
Not wearing PPE		
Removing safety guards from the workplace or equipment		
Servicing equipment which is in operation		

What are the other unsafe acts specific to Sri Lankan context?

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

Part 2: Influential Factors of Unsafe Behaviour of Construction Workers - Sri Lankan Industry perspective

I) Please indicate (with a tick) if the influential factors of unsafe behaviour of construction workers listed below are relevant to the construction workers in Sri Lankan context

Influential Factor	**Expert Response**	
Person (Individual Dynamics)	**Relevant**	**Irrelevant**
age		
Explain		
gender		
Explain		
experience		
Explain		
alcohol/drug abuse		
Explain		
education		
Explain		
attitude towards safety		
Explain		
psychological distress		
Explain		
income		
Explain		
Process (Work environment)	**Relevant**	**Irrelevant**
hazardous operations		
Explain		
unsafe conditions		
Explain		
hazardous equipment		
Explain		
Place (Organizational Safety Culture)	**Relevant**	**Irrelevant**
Safety Procedures and rules		
Explain		
management commitment		
Explain		
employee involvement		
Explain		
Safety communication		
Explain		
Other? ………………………………………………………………………………… …………………………………………………………………………………		

Thank you

Appendix 2: Main survey questionnaire

Master of Philosophy (Research)

Introduction

Unsafe behaviour of a construction worker is governed by many factors, both individual and external. This research is conducted to investigate the influential factors of unsafe behaviour of the construction workers and the degree of influence of those factors. The questionnaire consists of three parts covering demographic data, unsafe acts committed by construction workers and influential factors of unsafe behaviour.

Statement of Confidentiality

The information generated from this questionnaire will be used only for the purpose of completing the research. All the responses of the interviewees will be kept confidential. Further, to maintain the confidentiality, the actual names of the organisations and the respondents will not be revealed under any circumstance.

Researcher:

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Part 1: Respondent Profile

I) Name (Optional): ……………………………………………….

II) Age: …………………………………………………………..

III) Company (Optional):…………………………………………….

IV) Please state your labour category and experience

Category (Please indicate with a tick)		**Experience** (Years)
Carpenter		
Electrician		
Mason		
Plumber		
Welders		
Other (Specify)		

Part 2 : Unsafe Behaviour

Please rate your engagement in the following conducts/activities while working, using the provided Likert scale.

Unsafe Act	**1**-None of the time	**2**-A little of the time	**3**-some of the time	**4**-Most of the time	**5**-All of the time
Conduct					
I work with lack of concentration					
I work in poor fitness					
I throw or drop objects (materials and tools) from high levels					
I work even when I am drunk or high					
I smoke/create naked flame in areas where flammable materials are stored					
I horseplay around in the workplace					
I work without authority on the job					
I leave nails or other sharp objects protruding from surfaces					
Ergonomics					
I tend to work at improper speeds					
I use improper posture for tasks					
Tools and Equipment					
I use tools and equipment the way I please					
I don’t mind using defective equipment and tools					
I don’t wear PPE					
I remove safety guards& features from the workplace					
I service/maintain equipment& tools which is in operation					

Part 3 :Factors Influencing Unsafe Behaviour

3.1 Individual dynamics

I) Alcohol / Drug Abuse

Question	**Yes**	**No**
Do you use alcohol and/or any nonmedical drugs such as tobacco, ganja, heroin, cocaine etc.		
Have you ever felt that you ought to cut down on your drinking or drug use?		
Have people annoyed you by criticizing your drinking or drug use?		
Have you ever felt bad or guilty about your drinking or drug use?		
Have you ever had a drink or used drugs first thing in the morning to steady your nerves or to get rid of a hangover?		

II) What is your level of education?

1 –Up to GCE A/L /NVQ level 3 or above

2 –Up to technical Course (NVQ level 2)

3 –Below/Up to GCE O/L (Grade 6-11)

4 – Primary Education (below/Up to fifth grade)

5 - No formal education

III) Do you think that the Occupational Safety and Health at the workplace is of importance to a worker and to the company (attitude towards safety)

1 - Strongly agree

2 - Agree

3 - Neither agree nor disagree

4 - Disagree

5 - Strongly disagree

IV) Psychological distress

The following questions ask about how you have been feeling during the past 30 days. For each question, please circle the number that best describes how often you had this feeling.

During the past 30 days, about how often did you feel …	1- None of the time	2- A little of the time	3- some of the time	4- Most of the time	5- All of the time
a) … nervous					
b) … hopeless					
c) …restless or fidgety					
d) … so depressed that nothing could cheer you up?					
e) … that everything was an effort?					
f) …worthless?					

V) Income

Financial Stability

Question	**Response**				
	1- Strongly agree	**2-** Agree	**3-** Neither agree nor disagree	**4 -** Disagree	**5** -Strongly disagree
This job comes with a sufficient salary					
I have other means of income in addition to this job					

How many dependents do you have in your family?

1 – none
2 – one to two
3 – three
4 – four
5 – five or more

3.2 Work Environment

Question	1-None of the time	2-A little of the time	3- some of the time	4-Most of the time	5-All of the time
How often do you engage in hazardous operations on site? (Excavating, trenching, working at heights, Welding and Cutting, Blasting and the Use of Explosives etc.)					
How often do you find yourself surrounded by unsafe conditions on site? (ex. Unguarded machinery, manholes, debris, reinforcement bars, unguarded workspaces, etc.)					
How often do you use hazardous equipment* in work? (*hand tools, such as hammers, chisels, screwdrivers, spanners, saws, scissors, etc. *machines, such as drilling machines, portable power tools, floor polishing machines, power presses, circular saws, excavating equipment, lifting equipment, such as fork-lift trucks, vehicle hoists, lifting slings etc. *other equipment, such as ladders, kick stools, water pressure cleaners etc.)					

3.3 Organizational Safety Culture

Question	Response				
Safety Procedures & rules	**1-** Strongly agree	**2-** Agree	**3-** Neither agree nor disagree	**4-** Disagree	**5-** Strongly disagree
Procedures and rules are there					
They are helpful					
People are trained in them					
Procedures are updated over time for efficiency					
Management commitment	**1**	**2**	**3**	**4**	**5**
Safety is perceived to be in management's priorities					
They are often seen in the workplace					
They talk about safety when in the workplace and is this visible to the workforce					
They deal quickly and effectively with safety issues raised					
Management is trusted over safety					
Employee involvement in safety	**1**	**2**	**3**	**4**	**5**
People of all levels are involved in safety					
Individual employees are often asked for their input safety issues					
Employees often report unsafe conditions or near misses					
safety is regarded to be employees' responsibility					
Safety Communication	**1**	**2**	**3**	**4**	**5**
There is effective two-way communication about safety					
Safety information is easily available					
Safety programme of the company communicated to all levels					
People are open about safety					

Thank you for taking part in the survey.

Appendix 3: The Kessler K6

Date completed: __ __ / __ __ / __ __ __ __

K6+

Provider: ____________________

Provider ID:

|__|__|__|__|__|__|__|__|

Please use gummed label if available	Patient or Client Identifier:
Surname:	
Other names:	
Date of Birth: ___ ___ / ___ ___ / ___ ___ ___ ___	Sex: Male ☐1 Female ☐2
Address:	

The following questions ask about how you have been feeling during the past 30 days. For each question, please circle the number that best describes how often you had this feeling.

Q1. During the past 30 days, about how often did you feel …	**All of the time**	**Most of the time**	**Some of the time**	**A little of the time**	**None of the time**
a. …nervous?	1	2	3	4	5
b. …hopeless?	1	2	3	4	5
c. …restless or fidgety?	1	2	3	4	5
d. …so depressed that nothing could cheer you up?	1	2	3	4	5
e. …that everything was an effort?	1	2	3	4	5
f. …worthless?	1	2	3	4	5

Appendix 4: Health & safety climate survey tool by HSE

Question set	
1	**Management commitment** •Where is safety perceived to be in management's priorities (Senior/middle/1st line)? • How do they show this? • How often are they seen in the workplace? • Do they talk about safety when in the workplace and is this visible to the workforce? • Do they 'walk the talk'? • Do they deal quickly and effectively with safety issues raised? • What balance do their actions show between safety and production? • Are management trusted over safety?
2	**Communication** • Is there effective two-way communication about safety? • How often are safety issues discussed; • With line manager/subordinate? • With colleagues? • What is communicated about the safety programme of the company? • How open are people about safety?
3	**Employee involvement** • How are people (all levels, especially operators) involved in safety? • How often are individual employees asked for their input safety issues? • How often do operators report unsafe conditions or near misses etc? • Is there active, structured operator involvement e.g. workshops, projects, safety circles? • Is there a continuous improvement / total quality approach? • Whose responsibility is safety regarded to be? • Is there genuine cooperation over safety – a joint effort between all in the company?
4	**Training/information** •Do employees feel confident that they have all the training that they need • How accurate are employees' perceptions of hazards and risks? • How effective is safety training in meeting needs (including managers!)? • How are needs identified? • How easily available is safety information?
5	**Compliance with procedures** • What are written procedures used for? • What decides whether a particular task will be captured in a written procedure? • Are they read? • Are they helpful? • What other rules are there? • Are there too many procedures and rules? • How well are people trained in them? • Are they audited effectively? • Are they written by users? • Are they linked to risks?

6	**Motivation** • Do managers give feedback on safety performance (& how)? • Are they likely to notice unsafe acts? • Do managers (all levels - S/M/1st) always confront unsafe acts? • How do they deal with them? • Do employees feel they can report unsafe acts? • How is discipline applied to safety? • What do people believe are the expectations of managers? • Do people feel that this is a good place to work (why/why not)? • Are they proud of their company?
7	**Learning Organisation** • Does the company really learn from accident history, incident reporting etc? • Do employees feel confident in reporting incidents or unsafe conditions? • Do they report them? • Do reports get acted upon? • Do they get feedback?

Appendix 5: Training dataset

No.	Category	Age (IF-1)	Experience (IF-2)	Alcohol/Drug abuse (IF-3)	Education (IF-4)	Attitudes to safety (IF-5)	Psychological distress (IF-6)	Income (IF-7)	Hazardous operations (IF-8)	Unsafe conditions (IF-9)	Hazardous equipment (IF-10)	Safety Procedures and rules (IF-11)	Management commitment (IF-12)	Employee involvement in safety IF-13)	Safety Communication (IF-14)	Expected USBS
1	Aluminium worker	0.4	0.4	0.6	0.6	0.2	0.4	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.27
2	Carpenter	0.8	1	0.2	0.2	0.2	0.4	0.4	0.8	0.8	0.8	0.4	0.8	1	0.8	0.52
3	Concrete worker	1	1	0.8	1	0.4	0.6	0.4	0.8	0.8	0.4	0.8	0.8	0.6	0.8	0.36
4	Aluminium worker	0.6	0.8	0.6	0.6	0.2	0.4	0.6	0.4	0.8	0.2	0.2	0.2	0.2	0.2	0.28
5	Rigger	0.8	0.8	0.2	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.39
6	Bar-bender	0.8	0.8	0.2	0.6	0.6	0.6	0.8	1	1	0.8	0.2	0.2	0.4	0.4	0.39
7	Mason	0.2	0.2	0.2	0.2	0.6	0.2	0.6	0.6	0.8	0.6	0.4	0.4	0.2	0.4	0.20
8	Mason	0.6	0.4	0.2	1	0.4	0.2	0.6	0.8	1	0.8	0.4	0.2	0.4	0.2	0.23
9	Aluminium worker	1	1	0.2	0.2	0.4	0.2	0.6	0.2	0.6	0.2	0.4	0.2	0.4	0.2	0.23
10	Aluminium worker	1	1	0.6	0.2	0.2	0.4	0.6	0.2	0.6	0.2	0.2	0.2	0.2	0.2	0.53
11	Carpenter	0.6	0.8	0.2	0.2	0.2	0.2	1	0.6	0.4	0.8	0.2	0.2	0.2	0.2	0.21
12	Electrician	0.6	0.8	0.2	0.2	0.2	0.2	0.6	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.31

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
13	Welder	0.6	0.6	0.2	0.4	0.2	0.2	1	0.8	0.2	0.8	0.2	0.2	0.2	0.2	0.25
14	Mason	0.2	0.4	0.2	0.6	0.4	0.4	0.6	0.4	0.4	0.6	0.2	0.4	0.4	0.4	0.23
15	Mason	0.4	0.2	0.8	0.6	0.6	0.4	0.6	0.8	0.4	0.8	0.2	0.4	0.4	0.4	0.33
16	Carpenter	0.6	1	0.2	0.6	0.2	0.2	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.31
17	Electrician	1	1	0.8	0.8	0.4	0.4	0.6	0.8	0.8	0.2	0.4	0.4	0.4	0.4	0.28
18	Bar-bender	0.8	0.8	0.8	0.6	0.4	0.6	0.8	1	1	1	0.4	0.4	0.4	0.4	0.31
19	Concrete worker	1	1	1	0.6	0.2	0.2	1	0.6	0.4	0.6	0.2	0.4	0.4	0.4	0.52
20	Concrete worker	0.6	1	1	0.6	0.2	0.4	1	0.6	0.4	0.6	0.2	0.4	0.4	0.4	0.53
21	Electrician	1	1	0.2	0.2	0.2	0.4	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.37
22	Mason	0.6	0.8	0.2	0.2	0.2	0.2	0.8	0.4	0.8	0.6	0.6	0.6	0.4	0.4	0.28
23	Mason	1	1	0.2	0.6	0.2	0.4	0.4	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.21
24	Mason	0.8	0.8	0.4	0.6	0.4	0.6	1	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.60
25	Electrician	1	1	0.2	0.4	0.2	0.4	0.6	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.37
26	Mason	0.8	1	0.2	0.4	0.4	0.4	0.6	0.6	0.8	0.4	0.2	0.2	0.2	0.2	0.40
27	Mason	0.8	1	0.2	0.6	0.2	0.4	1	0.4	0.4	0.4	0.4	0.6	0.4	0.2	0.45
28	Plumber	0.8	0.8	0.2	0.6	0.2	0.4	0.6	0.2	0.8	0.8	0.4	0.4	0.4	0.4	0.32
29	Welder	0.8	0.8	0.4	0.2	0.2	0.2	0.4	0.2	0.8	0.8	0.2	0.2	0.2	0.2	0.32
30	Mason	0.4	0.4	0.4	0.6	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.20
31	Plumber	0.2	0.2	0.2	0.6	0.2	0.4	0.8	0.6	1	0.2	0.2	0.2	0.2	0.2	0.32
32	Welder	0.8	1	0.6	0.4	0.6	0.2	1	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.53
33	Electrician	0.6	0.6	0.2	0.2	0.2	0.2	0.8	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.20

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
34	Electrician	0.4	0.4	0.2	0.4	0.2	0.2	0.8	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.20
35	Rigger	0.4	0.2	0.4	0.6	0.2	0.2	0.4	0.8	1	1	0.2	0.2	0.2	0.2	0.20
36	Electrician	0.6	0.6	0.2	0.2	0.2	0.2	0.8	0.8	0.4	0.2	0.2	0.2	0.2	0.2	0.20
37	Rigger	0.6	0.6	0.2	0.6	0.2	0.4	0.6	1	0.8	1	0.4	0.4	0.2	0.4	0.35
38	Mason	0.2	0.2	0.4	0.6	0.2	0.2	0.6	0.2	0.6	0.8	0.2	0.2	0.2	0.2	0.20
39	Rigger	0.8	1	0.6	0.6	0.4	0.6	0.6	0.8	0.6	0.4	0.4	0.4	0.4	0.6	0.39
40	Mason	0.6	0.8	0.8	0.6	0.4	0.6	1	0.4	0.6	0.2	0.2	0.4	0.4	0.4	0.44
41	Mason	0.6	0.8	0.2	0.6	0.6	0.4	1	0.2	0.6	0.8	0.4	0.4	0.2	0.4	0.47
42	Concrete worker	0.4	0.8	0.2	0.6	0.4	0.4	0.6	0.4	0.4	0.2	0.4	0.2	0.4	0.4	0.41
43	Concrete worker	1	1	1	0.6	0.4	0.4	0.8	0.4	0.4	0.8	0.4	0.4	0.4	0.4	0.43
44	Bar-bender	0.6	0.6	0.2	0.6	0.2	0.4	0.6	1	1	1	0.2	0.4	0.6	0.4	0.36
45	Carpenter	0.6	0.8	0.2	0.2	0.2	0.4	0.6	0.4	0.4	0.2	0.4	0.2	0.4	0.4	0.31
46	Concrete worker	1	1	0.2	0.6	0.2	0.2	0.4	0.8	0.8	0.8	0.4	0.2	0.2	0.2	0.49
47	Mason	0.2	0.2	0.2	0.8	0.2	0.2	1	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.20
48	Mason	0.6	0.6	0.4	0.6	0.4	0.2	1	0.2	0.8	0.6	0.2	0.2	0.2	0.2	0.27
49	Rigger	0.6	0.8	0.2	0.6	0.2	0.2	0.2	0.8	1	1	0.2	0.2	0.2	0.2	0.37
50	Rigger	0.6	0.6	0.2	0.6	0.4	0.2	0.6	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.21
51	Mason	0.8	0.8	0.4	0.6	0.6	0.4	1	0.4	0.2	0.4	0.2	0.6	0.6	0.8	0.44
52	Carpenter	1	1	0.8	0.2	0.6	0.6	1	0.6	0.8	0.8	0.8	0.8	0.6	1	0.45
53	Plumber	0.4	0.6	0.2	0.6	0.2	0.2	0.6	0.8	0.8	0.4	0.4	1	0.6	0.8	0.35
54	Rigger	0.2	0.2	0.2	1	0.4	0.6	0.6	0.8	0.8	0.8	0.6	0.6	1	1	0.27

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
55	Electrician	0.8	1	0.2	0.6	0.2	0.6	1	0.8	0.8	0.8	0.4	0.6	0.4	0.6	0.52
56	Carpenter	0.6	0.8	0.4	0.2	0.2	0.4	0.6	1	1	0.4	0.6	0.8	0.6	1	0.27
57	Plumber	0.2	0.2	0.2	0.6	0.2	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.2	0.4	0.25
58	Carpenter	0.4	0.4	0.6	0.6	0.4	0.2	0.6	1	1	0.4	0.4	0.8	0.2	0.2	0.23
59	Carpenter	0.6	0.8	0.4	0.6	0.2	0.4	0.6	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.36
60	Bar-bender	0.6	0.8	0.8	0.6	0.2	0.4	0.2	0.4	0.2	0.2	0.4	0.2	0.2	0.2	0.43
61	Concrete worker	0.8	0.8	0.2	0.6	0.2	0.4	0.8	0.4	0.2	0.2	0.4	0.4	0.4	0.4	0.29
62	Rigger	0.6	0.8	0.6	0.6	0.2	0.4	0.8	0.8	1	0.2	0.4	0.2	0.2	0.2	0.37
63	Mason	0.4	0.2	0.4	0.4	0.2	0.2	0.4	0.6	0.8	0.6	0.4	0.2	0.2	0.2	0.36
64	Electrician	0.8	0.8	0.2	0.2	0.2	0.2	0.6	0.8	0.8	0.8	0.2	0.2	0.2	0.4	0.37
65	Concrete worker	1	1	0.4	0.8	0.6	0.6	0.8	0.4	0.8	0.6	0.4	0.6	0.6	0.8	0.60
66	Welder	0.8	1	0.4	0.4	0.4	0.6	1	1	1	1	0.4	0.6	0.8	0.8	0.39
67	Mason	0.8	0.8	0.2	0.2	0.2	0.2	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.4	0.33
68	Welder	1	1	0.6	0.6	0.6	0.6	1	1	1	1	0.4	0.4	0.8	0.6	0.53
69	Plumber	0.6	0.6	0.2	0.2	0.4	0.2	0.2	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.39
70	Mason	0.4	0.2	0.2	0.4	0.2	0.2	0.4	0.6	0.8	0.4	0.2	0.4	0.2	0.2	0.33
71	Mason	0.6	0.4	0.2	0.2	0.2	0.4	0.4	0.8	0.6	0.6	0.2	0.2	0.2	0.2	0.35
72	Electrician	0.8	0.8	0.4	0.2	0.2	0.2	1	0.8	0.6	0.6	0.2	0.2	0.2	0.2	0.37
73	Carpenter	0.4	0.4	0.2	0.4	0.2	0.2	0.6	0.6	0.6	0.6	0.4	0.6	0.4	0.4	0.31
74	Rigger	0.4	0.2	0.4	0.6	0.4	0.2	0.4	1	0.8	1	0.2	0.2	0.2	0.2	0.35
75	Carpenter	0.2	0.2	0.2	0.6	0.2	0.2	0.4	0.4	0.8	0.8	0.2	0.4	0.4	0.2	0.35

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
76	Carpenter	0.6	0.6	0.2	0.2	0.2	0.2	1	0.2	0.4	0.2	0.2	0.4	0.2	0.2	0.20
77	Rigger	0.4	0.2	0.2	0.2	0.2	0.2	1	0.8	0.4	0.2	0.4	0.6	0.6	0.6	0.37
78	Rigger	0.8	1	0.6	0.2	0.2	0.6	0.8	0.8	1	0.4	0.6	0.6	1	0.4	0.37
79	Mason	0.6	0.4	0.2	0.6	0.2	0.2	1	0.8	0.6	0.8	0.2	0.2	0.2	0.2	0.20
80	Welder	0.6	0.6	1	0.4	0.4	0.2	1	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.43
81	Plumber	0.6	0.6	0.4	0.6	0.6	0.2	0.6	0.6	0.8	0.6	0.2	0.4	0.4	0.2	0.36
82	Welder	0.6	0.4	0.2	0.2	0.2	0.2	0.4	0.8	0.8	0.2	0.2	0.2	0.6	0.2	0.20
83	Electrician	0.4	0.4	0.2	0.2	0.2	0.2	0.8	1	0.2	0.2	0.2	0.2	0.2	0.2	0.20
84	Rigger	0.4	0.4	1	0.6	0.2	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.53
85	Bar-bender	0.6	0.6	1	0.6	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
86	Mason	0.4	0.6	1	0.8	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
87	Rigger	0.4	0.2	1	0.6	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.32
88	Concrete worker	0.6	0.8	1	1	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.52
89	Bar-bender	0.8	1	1	0.6	0.2	0.4	0.8	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.48
90	Plumber	0.8	1	1	0.6	0.4	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
91	Carpenter	1	1	1	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.59
92	Concrete worker	0.8	0.8	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0.4	0.8	0.51
93	Mason	0.6	0.6	0.6	0.6	0.4	0.4	0.6	0.6	0.6	0.6	0.4	0.6	0	0.6	0.39
94	Welder	0.4	0.4	0.4	1	0.4	0.6	0.8	0.6	0.6	0.6	0.4	0.6	0.4	0.6	0.36
95	Mason	0.8	0.8	1	1	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.60
96	Mason	0.6	1	0.2	0.8	0.2	0.4	1	0.8	0.6	0.2	0.2	0.4	0.2	0.4	0.51

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
97	Carpenter	0.4	0.4	0.2	0.6	0.6	0.6	0.8	0.2	0.2	0.4	0.6	0.6	0.4	0.2	0.27
98	Carpenter	0.6	0.6	0.2	0.6	0.4	0.4	0.8	0.2	0.4	0.4	0.6	0.6	0.6	0.6	0.20
99	Electrician	0.6	0.6	0.2	0.2	0.2	0.2	0.6	1	0.8	0.2	0.6	0.6	0.6	0.8	0.47
100	Electrician	0.4	0.2	0.2	0.4	0.4	0.2	1	1	0.8	0.2	0.6	0.6	0.6	0.8	0.29
101	Mason	0.6	1	0.8	0.6	0.2	0.6	0.8	0.8	0.6	0.4	0.2	0.2	0.2	0.2	0.41
102	Mason	0.2	0.2	0.2	0.6	0.6	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.27
103	Mason	0.2	0.2	0.2	0.6	0.6	0.4	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.20
104	Mason	0.4	0.4	0.2	0.2	0.4	0.2	0.8	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.20
105	Mason	0.2	0.2	0.2	0.8	0.4	1	0.6	0.2	0.2	0.2	0.4	0.4	0.4	0.2	0.40
106	Mason	0.6	0.6	0.2	0.6	0.4	0.2	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.32
107	Mason	1	1	0.2	0.6	0.4	0.6	0.2	0.4	0.4	0.4	0.6	0.6	0.4	0.4	0.45
108	Mason	0.2	0.4	0.2	1	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.39
109	Mason	0.4	0.4	0.2	0.6	0.2	0.6	0.8	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.20
110	Carpenter	0.4	0.6	0.2	0.4	0.2	0.4	1	0.2	0.4	0.2	0.2	0.2	0.2	0.4	0.23
111	Carpenter	0.6	0.8	0.2	0.8	0.4	0.8	0.8	0.6	0.6	0.8	0.2	0.2	0.2	0.4	0.25
112	Rigger	0.4	0.2	0.2	0.8	0.6	0.2	1	0.8	0.2	0.2	0.4	0.4	0.4	0.4	0.20
113	Bar-bender	0.6	0.6	1	0.6	0.4	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.47
114	Electrician	0.6	0.8	0.6	0.4	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
115	Bar-bender	0.6	0.6	1	0.6	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
116	Rigger	0.4	0.4	0.2	0.6	0.2	0.4	0.6	1	1	1	0.2	0.2	0.4	0.2	0.35
117	Rigger	0.4	0.2	0.4	0.2	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.28

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
118	Plumber	0.8	1	0.2	0.4	0.2	0.4	0.4	0.8	1	0.6	0.4	0.6	0.6	0.6	0.49
119	Bar-bender	0.6	0.6	0.4	0.2	0.4	0.6	0.8	1	0.8	1	0.4	0.4	0.4	0.4	0.35
120	Mason	0.4	0.2	0.4	0.8	0.4	0.4	0.6	0.8	1	1	0.6	0.8	0.6	0.6	0.40
121	Rigger	0.4	0.8	0.6	0.8	0.2	0.4	0.4	0.8	0.8	0.8	0.8	0.4	0.6	0.8	0.45
122	Concrete worker	1	1	0.4	0.2	0.2	0.6	0.6	0.8	0.8	0.4	0.2	0.4	0.4	0.4	0.40
123	Concrete worker	1	1	0.6	0.6	0.6	0.4	0.8	0.8	1	0.8	0.6	0.4	0.4	0.6	0.43
124	Concrete worker	1	1	0.8	0.8	0.6	0.6	0.8	1	1	0.6	0.8	0.6	0.8	0.8	0.68
125	Rigger	0.4	0.4	0.4	0.4	0.2	0.6	0.8	0.8	0.8	0.2	0.8	0.4	0.8	0.6	0.47
126	Electrician	0.2	0.2	0.2	0.6	0.6	0.2	1	0.2	0.6	0.2	0.4	0.4	0.4	0.2	0.20
127	Rigger	0.2	0.2	0.2	0.6	0.2	0.2	0.2	1	0.2	0.8	0.2	0.2	0.2	0.2	0.20
128	Rigger	0.6	0.8	0.4	0.2	0.2	0.4	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.2	0.23
129	Mason	0.4	0.2	0.6	0.2	0.2	0.4	0.6	0.2	0.6	0.2	0.2	0.2	0.4	0.2	0.24
130	Plumber	0.4	0.6	0.8	0.8	0.4	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
131	Mason	0.6	0.8	0.4	0.6	0.4	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
132	Mason	0.6	0.6	1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.40
133	Carpenter	0.4	0.4	1	0.8	0.4	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.37
134	Concrete worker	0.2	0.4	0.4	1	0.4	0.6	1	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
135	Carpenter	0.2	0.2	1	0.6	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
136	Welder	0.8	1	1	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.49
137	Mason	0.2	0.2	1	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
138	Rigger	0.4	0.4	0.4	0.6	0.2	0.8	0.8	0.2	1	0.2	0.4	0.4	0.6	0.6	0.44

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
139	Bar-bender	0.4	0.6	1	0.6	0.2	0.2	0.6	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.20
140	Concrete worker	1	1	0.6	0.6	0.8	0.4	1	0.8	0.8	0.4	0.2	0.2	0.2	0.2	0.60
141	Bar-bender	0.2	0.2	0.2	0.6	0.2	0.4	1	0.8	1	1	0.4	0.4	0.4	0.4	0.25
142	Electrician	0.6	0.8	0.2	0.4	0.2	0.4	1	1	1	1	1	1	0.6	0.8	0.48
143	Rigger	0.4	0.6	0.6	0.2	0.2	0.4	0.8	0.4	0.2	0.2	0.2	0.4	0.4	0.4	0.35
144	Welder	0.6	0.8	0.8	0.8	0.6	0.6	1	1	1	1	0.4	1	0.8	0.8	0.45
145	Concrete worker	0.4	1	0.2	0.6	0.2	0.4	0.6	0.8	0.8	0.2	1	0.8	0.8	0.4	0.47
146	Carpenter	0.6	0.4	0.2	0.6	0.2	0.4	0.4	1	0.8	0.8	1	0.8	0.6	0.8	0.39
147	Mason	0.6	0.4	0.2	1	1	0.2	0.8	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.29
148	Bar-bender	0.4	0.6	0.8	0.6	0.2	0.2	0.6	0.2	0.6	0.2	0.6	0.2	0.2	0.4	0.52
149	Welder	0.6	0.6	0.2	0.2	0.2	0.2	0.6	1	0.2	1	0.2	0.2	0.2	0.2	0.20
150	Carpenter	0.8	0.8	0.6	0.6	0.2	0.2	0.6	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.21
151	Rigger	0.6	0.6	0.8	0.2	0.2	0.6	0.8	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.43
152	Bar-bender	0.6	0.4	0.2	0.6	0.2	0.2	1	0.4	0.8	0.8	0.2	0.2	0.2	0.2	0.20
153	Mason	0.6	0.6	0.2	0.2	0.2	0.4	0.6	0.4	0.8	0.8	0.2	0.2	0.2	0.2	0.20
154	Mason	0.8	0.8	0.6	0.2	0.2	0.4	0.8	0.4	0.8	0.8	0.2	0.2	0.2	0.2	0.51
155	Carpenter	0.4	0.2	0.6	0.6	0.2	0.4	0.6	0.4	0.8	0.8	0.2	0.2	0.2	0.2	0.23
156	Mason	0.2	0.6	0.2	0.8	0.6	0.2	1	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.20
157	Mason	0.4	0.8	0.2	1	0.6	0.6	0.8	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.40
158	Mason	0.6	0.8	0.2	1	0.4	0.6	0.8	0.6	0.6	0.4	0.6	0.4	0.8	0.4	0.44
159	Mason	0.4	0.4	0.6	0.8	0.2	0.6	0.6	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
160	Welder	0.2	0.2	0.6	0.8	0.2	0.6	0.8	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
161	Mason	0.6	0.8	0.4	1	0.2	0.6	0.8	0.6	0.6	0.6	0.4	0.6	0.6	0.6	0.39
162	Aluminium worker	1	1	0.2	0.6	0.6	0.4	0.6	0.4	0.8	0.4	0.4	0.6	0.4	0.4	0.52
163	Welder	0.8	1	0.8	0.6	0.6	0.8	0.8	1	1	1	0.6	0.6	0.4	0.4	0.59
164	Mason	0.4	0.4	0.2	0.8	0.4	0.2	0.6	0.8	1	0.4	0.2	0.2	0.2	0.2	0.37
165	Mason	0.2	0.2	0.2	0.6	0.2	0.2	0.6	0.8	0.8	0.6	0.2	0.2	0.2	0.2	0.35
166	Mason	0.4	0.6	0.2	0.6	0.2	0.4	0.6	0.8	0.8	0.8	0.4	0.2	0.2	0.2	0.37
167	Mason	0.4	0.8	0.2	0.6	0.4	0.4	0.6	0.8	0.8	0.8	0.4	0.2	0.2	0.2	0.32
168	Carpenter	0.6	0.8	0.8	1	0.2	0.6	0.8	1	1	0.8	0.2	0.2	0.4	0.2	0.51
169	Electrician	0.8	1	0.4	0.4	0.4	0.4	0.6	0.8	1	0.8	0.4	0.4	0.4	0.2	0.52
170	Welder	1	1	0.2	0.6	0.6	0.4	0.6	0.8	0.8	1	0.4	0.4	0.4	0.2	0.63
171	Rigger	0.2	0.2	0.2	0.4	0.6	0.2	0.8	1	1	0.8	0.4	0.2	0.2	0.2	0.31
172	Bar-bender	0.6	0.8	0.8	0.2	0.2	0.4	0.6	1	1	1	0.2	0.2	0.4	0.2	0.43
173	Rigger	0.8	1	0.6	0.6	0.6	0.4	1	1	0.8	1	0.4	0.6	0.4	0.4	0.41
174	Mason	0.4	0.4	0.6	0.8	0.6	0.2	0.6	0.8	0.8	0.6	0.2	0.2	0.2	0.4	0.35
175	Mason	0.6	0.6	0.4	0.6	0.6	0.4	0.6	0.6	0.8	0.6	0.4	0.2	0.4	0.2	0.39
176	Rigger	1	1	0.2	0.6	0.6	0.4	1	1	1	1	0.4	0.4	0.4	0.4	0.48
177	Welder	1	1	0.4	0.6	0.6	0.4	1	1	1	1	0.4	0.6	0.4	0.4	0.48
178	Carpenter	0.4	0.4	0.2	0.6	0.2	0.2	0.6	0.8	1	0.8	0.2	0.2	0.2	0.2	0.32
179	Electrician	0.4	0.4	0.2	0.4	0.2	0.2	0.4	1	1	1	0.2	0.2	0.2	0.2	0.32
180	Rigger	0.8	0.8	0.4	0.6	0.6	0.4	1	1	1	1	0.4	0.4	0.4	0.4	0.51

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
181	Plumber	0.8	0.8	0.6	0.4	0.6	0.2	0.6	0.8	0.8	0.8	0.4	0.4	0.6	0.4	0.53
182	Welder	0.6	0.8	0.2	0.2	0.2	0.2	0.6	1	1	1	0.2	0.2	0.2	0.2	0.40
183	Electrician	0.6	0.8	0.2	0.4	0.2	0.2	0.6	0.8	1	1	0.2	0.2	0.2	0.2	0.41
184	Carpenter	0.2	0.2	0.6	0.8	0.4	0.2	1	0.6	1	0.8	0.2	0.2	0.4	0.4	0.37
185	Mason	0.2	0.2	0.2	0.6	0.2	0.2	0.4	0.8	1	0.6	0.2	0.2	0.2	0.2	0.32
186	Welder	0.8	1	0.2	0.6	0.6	0.2	0.8	1	1	1	0.4	0.4	0.4	0.4	0.47
187	Carpenter	0.6	0.4	0.6	0.6	0.6	0.2	0.6	0.8	1	0.8	0.2	0.4	0.2	0.4	0.37
188	Plumber	0.6	0.8	0.6	0.4	0.4	0.4	0.8	0.8	1	0.8	0.2	0.2	0.2	0.4	0.39
189	Plumber	0.6	0.8	0.4	0.4	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.4	0.4	0.2	0.44
190	Electrician	0.8	1	0.2	0.4	0.4	0.2	0.6	1	1	1	0.2	0.2	0.2	0.2	0.40
191	Electrician	0.8	1	0.4	0.4	0.4	0.2	0.8	1	1	1	0.4	0.2	0.2	0.4	0.47
192	Mason	0.4	0.2	0.2	0.6	0.2	0.2	0.6	0.8	1	0.6	0.2	0.2	0.2	0.2	0.33
193	Carpenter	0.2	0.2	0.6	0.8	0.2	0.4	1	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.29
194	Rigger	0.2	0.2	0.2	0.8	0.2	0.2	0.6	1	1	1	0.2	0.4	0.2	0.2	0.32
195	Mason	0.6	0.8	0.2	0.2	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.4	0.2	0.2	0.40
196	Rigger	0.4	0.2	0.4	0.8	0.4	0.2	0.6	0.8	0.8	0.8	0.2	0.2	0.4	0.2	0.28
197	Bar-bender	0.6	0.4	0.2	0.4	0.4	0.2	0.4	0.8	0.8	0.8	0.2	0.4	0.2	0.2	0.28
198	Concrete worker	1	1	0.6	0.6	0.6	0.4	0.8	0.6	1	0.6	0.4	0.6	0.8	0.6	0.59
199	Plumber	0.6	0.6	0.4	0.6	0.4	0.2	0.8	0.6	0.8	0.6	0.4	0.4	0.4	0.2	0.31
200	Concrete worker	1	1	0.4	0.8	0.6	0.2	0.8	0.6	0.8	0.6	0.4	0.6	0.6	0.6	0.49
201	Mason	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.27

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
202	Rigger	0.2	0.2	0.2	0.8	0.4	0.2	1	0.8	1	0.8	0.4	0.4	0.2	0.2	0.27
203	Mason	0.4	0.2	0.2	0.2	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.27
204	Carpenter	0.4	0.4	0.4	0.4	0.2	0.2	0.6	0.6	0.8	0.8	0.2	0.2	0.2	0.2	0.29
205	Mason	0.6	0.4	0.8	1	0.6	0.6	1	0.8	0.8	0.6	0.6	0.4	0.4	0.6	0.40
206	Plumber	0.6	0.6	0.2	0.2	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.31
207	Bar-bender	0.8	0.8	0.2	0.6	0.2	0.2	0.4	1	0.8	1	0.2	0.2	0.2	0.2	0.33
208	Welder	1	1	0.4	0.4	0.4	0.2	1	1	1	1	0.4	0.2	0.2	0.4	0.45
209	Concrete worker	1	1	0.6	0.6	0.6	0.4	0.8	0.6	1	0.6	0.6	0.6	0.4	0.4	0.60
210	Mason	0.2	0.4	0.2	0.4	0.2	0.2	0.4	0.6	0.6	0.6	0.2	0.2	0.2	0.4	0.29
211	Electrician	0.8	1	0.2	0.2	0.2	0.2	0.4	1	0.6	0.8	0.2	0.2	0.2	0.2	0.33
212	Carpenter	0.2	0.2	0.2	1	0.6	0.2	0.8	0.6	0.8	0.8	0.2	0.2	0.2	0.2	0.31
213	Mason	0.4	0.2	0.2	0.4	0.2	0.2	0.4	0.6	0.6	0.6	0.2	0.2	0.2	0.2	0.28
214	Bar-bender	0.6	0.8	0.8	0.6	0.6	0.2	1	0.8	0.8	1	0.6	0.6	0.6	0.6	0.40
215	Rigger	0.6	0.6	0.2	0.2	0.2	0.2	0.4	1	0.6	0.8	0.2	0.2	0.2	0.2	0.29
216	Mason	0.6	0.6	0.2	0.4	0.2	0.2	0.4	0.8	0.8	0.6	0.2	0.2	0.2	0.4	0.39
217	Concrete worker	1	1	0.6	0.8	0.6	0.6	1	0.6	1	0.6	0.6	0.4	0.4	0.6	0.56
218	Electrician	0.8	0.8	0.2	0.2	0.2	0.2	0.2	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.35
219	Welder	1	0.8	0.6	0.6	0.6	0.2	1	0.8	0.8	0.8	0.6	0.6	0.6	0.4	0.48
220	Electrician	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.8	1	0.8	0.2	0.4	0.4	0.2	0.32
221	Mason	0.6	0.4	0.2	0.6	0.4	0.2	0.6	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.35
222	Plumber	0.8	1	0.2	0.4	0.4	0.2	1	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.41

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
223	Rigger	0.4	0.4	0.2	0.6	0.2	0.2	0.6	0.8	1	0.8	0.2	0.2	0.2	0.2	0.28
224	Bar-bender	0.6	0.8	0.2	0.2	0.2	0.2	0.6	0.8	1	0.8	0.2	0.2	0.2	0.2	0.28
225	Mason	0.6	0.6	0.2	0.4	0.2	0.2	0.4	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.32
226	Welder	1	1	0.6	0.8	0.6	0.6	0.8	1	0.8	1	0.6	0.6	0.6	0.4	0.59
227	Concrete worker	1	1	0.4	0.6	0.6	0.4	1	0.6	0.8	0.4	0.6	0.4	0.6	0.6	0.56
228	Carpenter	0.2	0.2	0.4	0.6	0.4	0.2	0.6	0.8	0.4	0.4	0.2	0.2	0.2	0.2	0.33
229	Mason	0.4	0.4	0.2	0.6	0.4	0.2	0.4	0.8	1	0.6	0.2	0.4	0.2	0.4	0.31
230	Electrician	0.6	0.8	0.2	0.2	0.2	0.2	0.4	1	1	1	0.2	0.2	0.2	0.2	0.29
231	Bar-bender	1	1	0.6	0.6	0.6	0.4	1	0.8	1	0.8	0.4	0.4	0.6	0.4	0.52
232	Rigger	0.4	0.4	0.2	0.4	0.2	0.2	0.6	1	1	0.8	0.2	0.2	0.2	0.2	0.29
233	Concrete worker	1	1	0.8	0.6	0.6	0.6	0.8	0.8	1	0.6	0.6	0.6	0.4	0.4	0.59
234	Welder	0.8	0.8	0.4	0.6	0.6	0.2	1	1	1	1	0.6	0.6	0.4	0.6	0.36
235	Plumber	0.6	0.6	0.2	0.4	0.2	0.2	0.8	0.8	0.8	0.6	0.4	0.6	0.4	0.4	0.32
236	Rigger	0.4	0.2	0.2	0.6	0.2	0.2	0.4	1	1	1	0.4	0.2	0.2	0.2	0.29
237	Plumber	0.2	0.2	0.8	1	0.6	0.2	0.8	0.6	0.8	0.6	0.6	0.6	0.4	0.6	0.41
238	Mason	0.4	0.2	0.2	0.8	0.6	0.2	1	0.8	1	0.6	0.4	0.6	0.4	0.4	0.35
239	Electrician	0.4	0.2	0.2	0.6	0.4	0.2	0.6	0.8	1	0.8	0.4	0.4	0.4	0.4	0.35
240	Mason	0.6	0.6	0.2	0.4	0.2	0.2	0.6	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.40
241	Electrician	0.8	0.8	0.4	0.6	0.4	0.4	0.8	0.8	1	0.8	0.2	0.4	0.4	0.2	0.44
242	Welder	1	1	0.2	0.6	0.4	0.6	0.6	1	1	1	0.4	0.6	0.4	0.4	0.52
243	Bar-bender	0.6	0.8	0.2	0.6	0.2	0.2	0.6	1	1	1	0.4	0.4	0.2	0.2	0.36

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
244	Plumber	0.2	0.2	0.4	0.4	0.2	0.2	0.4	0.6	0.8	0.6	0.4	0.2	0.2	0.2	0.36
245	Rigger	0.6	0.8	0.2	0.2	0.2	0.2	0.6	0.8	0.8	0.8	0.2	0.2	0.2	0.4	0.37
246	Concrete worker	1	1	0.4	0.8	0.6	0.6	0.8	0.4	0.8	0.6	0.4	0.6	0.6	0.8	0.60
247	Welder	0.8	0.8	0.4	0.4	0.4	0.6	1	1	1	1	0.4	0.6	0.8	0.8	0.39
248	Carpenter	0.8	0.8	0.2	0.2	0.2	0.2	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.4	0.33
249	Rigger	0.8	1	0.6	0.6	0.6	0.6	1	1	1	1	0.4	0.4	0.8	0.6	0.53
250	Mason	0.6	0.6	0.2	0.2	0.4	0.2	0.2	0.6	0.8	0.6	0.2	0.2	0.2	0.2	0.39
251	Mason	0.4	0.2	0.2	0.4	0.2	0.2	0.4	0.6	0.8	0.4	0.2	0.4	0.2	0.2	0.33
252	Mason	0.6	0.6	0.2	0.2	0.2	0.4	0.4	0.8	0.6	0.6	0.2	0.2	0.2	0.2	0.35
253	Electrician	0.8	0.8	0.4	0.2	0.2	0.2	1	0.8	0.6	0.6	0.2	0.2	0.2	0.2	0.37
254	Plumber	0.4	0.4	0.2	0.4	0.2	0.2	0.6	0.6	0.6	0.6	0.4	0.6	0.4	0.4	0.31
255	Rigger	0.2	0.2	0.4	0.6	0.4	0.2	0.4	1	0.8	1	0.2	0.2	0.2	0.2	0.35
256	Mason	0.2	0.2	0.2	0.6	0.2	0.2	0.4	0.4	0.8	0.8	0.2	0.4	0.4	0.2	0.35
257	Plumber	0.8	0.8	0.2	0.2	0.2	0.2	0.4	0.4	0.6	0.4	0.2	0.2	0.4	0.4	0.40
258	Mason	0.4	0.2	0.2	0.4	0.2	0.2	0.4	0.4	0.6	0.4	0.2	0.2	0.4	0.2	0.32
259	Electrician	0.6	0.4	0.2	0.2	0.2	0.2	0.2	0.8	0.6	0.6	0.2	0.4	0.4	0.4	0.33
260	Mason	0.2	0.2	0.2	0.6	0.2	0.2	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.31
261	Carpenter	1	1	0.8	0.6	0.4	0.4	0.8	0.8	1	0.8	0.4	0.4	0.6	0.6	0.59
262	Plumber	0.4	0.6	0.6	0.8	0.8	0.4	1	0.4	0.8	0.6	0.4	0.8	0.8	0.4	0.44
263	Electrician	0.8	1	0.2	0.4	0.4	0.2	0.6	0.8	0.8	0.8	0.2	0.6	0.4	0.4	0.44
264	Electrician	0.6	0.6	0.4	0.2	0.2	0.2	0.6	1	0.6	0.4	0.2	0.4	0.4	0.2	0.31

No.	Category	IF-1	IF-2	IF-3	IF-4	IF-5	IF-6	IF-7	IF-8	IF-9	IF-10	IF-11	IF-12	IF-13	IF-14	Expected USBS
265	Mason	0.4	0.2	0.2	0.4	0.2	0.2	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.35
266	Carpenter	0.6	0.6	0.6	0.6	0.6	0.4	1	0.6	0.8	0.8	0.6	0.6	0.6	0.6	0.41
267	Mason	0.4	0.2	0.4	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.2	0.2	0.6	0.4	0.33
268	Carpenter	0.8	1	0.6	0.6	0.4	0.4	0.6	0.6	0.6	0.8	0.4	0.6	0.4	0.6	0.53
269	Welder	0.6	0.8	0.2	0.2	0.2	0.4	0.6	1	1	1	0.4	0.6	0.4	0.4	0.33
270	Carpenter	0.4	0.6	1	0.8	0.8	0.4	1	0.6	0.8	0.6	0.6	0.6	0.6	0.6	0.56
271	Mason	0.2	0.2	0.2	0.4	0.2	0.2	0.6	0.4	0.4	0.4	0.2	0.4	0.4	0.2	0.28
272	Rigger	1	1	0.6	0.8	0.6	0.6	1	1	1	1	0.6	0.6	0.6	0.8	0.60
273	Carpenter	1	1	0.8	0.8	0.6	0.4	1	0.6	0.6	0.8	0.6	0.6	0.8	0.6	0.60
274	Electrician	1	1	0.2	0.2	0.2	0.4	1	0.8	0.8	0.8	0.6	0.6	0.4	0.6	0.39
275	Concrete worker	1	1	0.4	0.8	0.6	0.4	1	0.4	0.8	0.4	0.6	0.6	0.8	0.6	0.55
276	Welder	1	1	0.6	0.6	0.6	0.4	0.6	1	1	1	0.4	0.2	0.4	0.2	0.49
277	Mason	0.4	0.2	0.6	0.8	0.4	0.4	0.8	0.6	0.8	0.6	0.2	0.2	0.6	0.4	0.40

Appendix 6: List of publications

Research papers published and presented in international conferences:

- Manjula N.H.C., and De Silva, N., (2013).Strengthening the safety culture for organizational sustainability. In *proceedings of the CIOB 2nd World Construction Symposium, 2013,* 14th-15th June 2013, Colombo, Sri Lanka
- Manjula N.H.C., and De Silva, N., (2013). A study on the factors affecting safety behaviour of construction workers. *FARU International Research Symposium*, 13th-14th December 2013, Hambantota, Sri Lanka.
- Manjula N.H.C., and De Silva, N., (2014). Factors influencing safety behaviours of construction workers. In *proceedings of the CIOB 3rd World Construction Symposium, 2014,* 20th -22ndJune 2014, Colombo, Sri Lanka.