School of Psychology and Speech Pathology

Lagged Relationships between a Multilevel Model of Safety Climate and Employee Safety Outcomes

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: ………………………………………….

Date: ………………………..

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Abstract

In Zohar's Multilevel Model of Safety Climate (Zohar, 2000; 2003; Zohar & Luria, 2005), workers' perceptions of their supervisor and manager's commitment to safety are separately assessed and aggregated to the group and organisational level respectively. Treating safety climate as a multilevel construct has a number of conceptual and methodological advantages over the traditional single-level approach; however few researchers have adopted this practice and examined the cross-level or the lagged effects of safety climate.

In the current thesis, the cross-level and lagged relationships safety climate has with safety outcomes was investigated through the use of a recently developed multilevel safety climate survey in the Australian oil and gas context. Data was collected over a two year period in a single organisation. The survey consisted of three scales, separately examining manager, supervisor, and co-worker commitment to safety. Safety outcomes were operationalized as self-reported near misses and injuries.

The assessment of cross-level and lagged relationships involved a number of analyses, distributed across five objectives. In Objective One the factorial validity of the scales was assessed using confirmatory factor analysis. In Objective Two the cross-sectional criterion validity of the scales was examined using multilevel logistic regression in order to determine whether commitment to safety at each level of the organisation was associated with safety outcomes. In Objective Three, the predictive validity of each scale was assessed using multilevel Poisson regression in order to determine whether safety climate scores in Year One were predictive of safety outcomes in Year Two. In Objective Four, a series of path models were compared using path analysis in order to examine cross-level relationships between manager, supervisor, and co-worker commitment to safety. This analysis allowed the replication of Zohar and Luria's (2005) findings, and could determine whether Zohar's model could be extended to include perceptions of co-workers. In Objective Five, comparisons were made between safety climate operationalized at the individual and aggregate level, given the inconsistent labelling of safety climate at both levels of analysis despite the possibility that they may be distinct constructs.

While all three scales demonstrated acceptable factorial validity, only the supervisor and manager scales provided evidence of criterion and predictive validity through significant associations with self-reported near misses. Path model comparisons provided support for Zohar's Multilevel Model of Safety Climate and further suggested that co-workers were of lesser importance in promoting safety compared to supervisors and managers.

Comparisons between safety climate operationalized at the individual and aggregate level demonstrated that level of analysis did affect that pattern of relationships between safety climate and self-reported near misses. While aggregated co-worker safety climate was the weakest predictor of self-reported near misses, individual level co-worker safety climate was the strongest predictor even after controlling for higher level variance. Analyses further indicated that individual level co-worker safety climate mediated the relationship between aggregated supervisor safety climate and individual level self-reported near misses.

While replication of these findings is necessary, the results overall supported Zohar's Multilevel Model of Safety Climate and suggested that the model could be extended to include individual level perceptions of co-workers. Results also indicated that level-of-analysis has a potentially important effect on the pattern of relationships between safety climate and safety outcomes.

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Chapter 1

Introduction

1.1 Overview

In the period between June 2005 and June 2006, 690,000 Australians, or 6.4% of the working population, experienced a work-related injury or illness (Australian Bureau of Statistics, 2007). The total cost of these injuries was conservatively estimated to be $58b (National Occupational Health and Safety Commission, 2004). The oil and gas industry is one context where injuries are an ever present concern, with employees working with flammable liquids and high pressure in sometimes hostile operating conditions (Australian Petroleum Production and Exploration Association, 2011). While recording a lower frequency of lost-time injuries (LTI) compared to the mining industry (Department of Mines and Petroleum, 2011), LTI frequency is still appreciably higher compared to industries in less precarious environments, such as retail, media, education, and finance (Worksafe, 2010). Additionally, while the Australian oil and gas industry’s safety record has improved substantially in recent times, with LTI frequency nearly halving in the last few years, the overall frequency is still higher than many countries (International Association of Oil and Gas Producers [OGP], 2011). OGP statistics indicate that Australia’s LTI frequency of 0.71 per million work hours is higher than the average in the Asia-Australasia region (0.29), North America (0.48), South America (0.61), and the Middle East (0.25). Therefore, the oil and gas industry in Australia represents an area where there is room for substantial improvement in the frequency of work-related injury and illness.

In an attempt to minimise the injuries, mortality and economic losses that result from poor workplace safety, a significant body of research has evolved to promote understanding of the factors that contribute to workplace accidents (Seo, Torabi, Blair, & Ellis, 2004). Early research in the safety field focused on engineering or technical solutions to safety problems, however it became apparent to organisations and researchers that the majority of workplace injuries were not the result of technical malfunctions or inadequate engineering safeguards (Hale & Hovden, 1998), but had significant human contributions. One pertinent and often cited example is the Chernobyl nuclear reactor disaster, in which operating procedures were ignored and a multitude of safety systems were disabled by employees due to a variety of individual and organisational factors (Pidgeon & O'Leary, 2000). Another focus of early safety research was on human factors such as attitudes and compliance; however this too failed to completely explain the causes of safety outcomes (Hale & Hovden, 1998). This led to what Hale and Hovden described as the third age of safety research, where organisational variables such as safety climate and safety culture were of interest.

Safety climate refers to shared perceptions of an organisation's safety priority (e.g. Neal, Griffin, & Hart, 2000; Cooper & Phillips, 2004; Zohar & Luria, 2005; Huang, Chen, DeArmond, Cigularov, & Chen, 2007; Neitzel, Seixas, Harris, & Camp, 2008). The construct has steadily developed both theoretically and methodologically over the past 30 years, particularly in the last decade with the advent of detailed conceptual models by authors such as Zohar (2000; 2003; Zohar & Luria, 2005) and Flin (2007). These models propose a multilevel conceptualisation of safety climate, where perceptions of safety's priority among supervisors and managers are measured separately and aggregated to different levels of the organisation (Flin, 2007; Zohar & Luria, 2005), reflecting the separate influences that these hierarchical levels of the organisation have on an employee (Simard & Marchand, 1997; Tomas, Melia, & Oliver, 1999). However, this multilevel phase of safety research is still in its early stages. Further studies are required to identify the lagged/longitudinal relationships that safety climate has with safety outcomes, in order to improve the predictive qualities of safety climate surveys. No study to date has examined safety climate's lagged relationships with safety outcomes in the oil and gas industry while utilising the multilevel approach to measurement, with few multilevel studies conducted outside of the manufacturing sector.

In addition, there is the possibility of further conceptual development of the construct. While the influence of supervisor and management commitment to safety on safety outcomes is well established in the safety climate literature, little research has examined the role of co-workers. Research in related fields has suggested that co-workers are an important and distinct source of behavioural norms (e.g. Roy, 2003; Zhou, Fang, & Wang, 2008) and so further research is required to determine whether existing conceptual models can be extended to include perceptions of co-workers.

1.2 The Current Study

The overarching aim of this thesis is to identify lagged relationships between safety climate and the subsequent impact it has on safety outcomes, with safety outcomes operationalized as self-reported near misses and injuries. In the literature review to follow I will argue that these lagged relationships will best be identified through an analysis of interactions at the manager, supervisor, and co-worker level. Identification of these lagged relationships will allow organisations to diagnose potential safety deficiencies and plan improvements to organisational processes, with the aim of reducing the possibility of employee injury. The research for this thesis takes place in the oil and gas industry in Australia. Given the absence of studies investigating lagged relationships using a multilevel design in this context, coupled with the high injury rate in the Australian oil and gas industry as compared to other regions (OGP, 2011), the findings will be of practical and theoretical importance.

1.3 Format of Thesis

The format of the thesis is as follows.

In Chapter Two, a review of the literature will be undertaken in order to find common threads among the safety climate studies despite the different measures, conceptualisations of climate, outcome criteria, and analytic techniques used in research. The chapter will present a conceptual model of safety climate based on the work of Zohar (2000; 2003; Zohar & Luria, 2005) and discuss areas where further research is required.

Chapter Three will describe the rationale, aims and hypotheses of the thesis, while Chapter Four will outline the research methodology, including an overview of the research design, participants, measures, and procedure. A number of analyses will then be presented in order to further our understanding of safety climate and its relationship with safety outcomes. Chapter Five will outline Objective One, in which the factorial validity of the safety climate survey will be assessed. Since the thesis uses a survey not yet featured in the literature, an assessment of factorial validity is necessary to ensure that employees can differentiate between the behaviours listed in the scales, yet also perceive them belonging to the same underlying construct. This analysis marks the first step in providing support for Zohar's Multilevel Model of Safety Climate, given the survey utilises behavioural domains that Zohar similarly uses.

Chapter Six will outline Objective Two, in which cross-sectional analyses will be conducted between safety climate and safety outcomes at each level of the organisation. This will provide an indication of each scale's criterion validity. The analysis also serves as an exploratory examination of whether a multilevel model of safety climate is applicable to an oil and gas environment.

Chapter Seven will build upon what was discussed in Chapter Six by examining the predictive validity of the each scale in the multilevel safety climate survey (Objective Three). As stated previously, longitudinal studies are rare in the safety climate literature, with the majority of studies cross-sectional in design. By utilising a longitudinal design, causal statements can be made regarding the relationship between safety climate and safety outcomes. Given that predictive validity is the most critical feature of a scale and that safety climate scales are used for the diagnosis of potential safety deficiencies in an organisation, this analysis also importantly provides the first indication of the scale's utility as a diagnostic tool. The analysis also has theoretical ramifications, given that no study to date has tested the predictive validity of a multilevel safety climate survey in the oil and gas industry.

Chapter Eight will outline Objective Four, in which longitudinal relationships between separate levels of the organisation and safety outcomes will be assessed. A series of five multilevel path models will be compared, as this will allow the replication and extension of the work of Zohar and Luria (2005), and provide insight into the lagged relationships among the nested levels of safety climate and safety outcomes given the absence of research on this topic.

Chapter Nine will outline Objective Five, in which the effect that level-of-analysis has on the pattern of relationships between safety climate and safety outcomes will be investigated. Comparisons will be made between safety climate operationalized at the aggregate and individual levels in order to understand whether research conducted at the individual level is potentially confounded, and whether safety climate operationalized at the individual level should be considered a distinct construct to safety climate operationalized at the aggregate level.

Finally in Chapter Ten, the overall findings of the research will be discussed. Particular attention will be paid towards the theoretical implications of the findings, especially in regards to Zohar's Multilevel Model of Safety Climate, and the practical implications for organisations utilising safety climate surveys. In addition, the strengths and limitations of the thesis will be addressed, before a discussion of future directions that safety climate research can take.

Chapter 2

Review of the Literature

2.1 History of Climate Research

The origins of safety climate can be traced to the 1930's, with Lewin, Lippit and White's (1939) study on experimentally created "social climates". In this classic study, Lewin and colleagues had leaders at an American summer camp create an authoritarian, democratic, or laissez-faire atmosphere through their leadership techniques. The climate created had a significant impact on the children, for example when an authoritarian climate was created the children tended to be more apathetic when the leader was present, and more aggressive when the leader was absent. Though the authors did not give any details on how climate as a construct should be measured or conceptualized, the study marked a turning point in that aggressive behaviour was seen to be a product of group processes rather than simply a product of individual attributes. Lewin (1951) continued in this vein of research through his classic heuristic of B = f(P, E), in other words, an individual's behaviour (B) is a function of both his or her person (P) (e.g. individual attributes) and environment (E). The term 'organisational climate' originated from these efforts to describe the organisational (i.e. environmental) variables that influence behaviour.

Argyris (1958) first defined the term "organisational climate" in his study of group dynamics in a bank, where he described the organisational environment in terms of formal organisational policies and individual variables such as employee values and personality. It was a very ambiguous term describing the organisational situation, and little changed definition-wise in the following decades. Though the construct took shape in the 1960's with the operationalization of climate through employee perceptions and with more comprehensive frameworks of climate proposed by authors such as Litwin and Stringer (1968), the conceptual ambiguity persisted with researchers commonly contradicting one another in terms of climate definition, dimensionality, and measurement. This led Glick (1985, p. 601) to describe organisational climate as a "conceptual morass" and Guion (1973, p. 121) to state that organisational climate is "…one of the fuzziest concepts to come along in a long time".

James and Jones (1974) attempted to provide some coherency and structure to organisational climate research through their review of the literature. The authors categorised organisational climate research as belonging to one of three approaches. The first approach was the multiple measurement-organisational attribute approach, which regarded organisational climate as an organisational attribute (in comparison to an individual attribute) that could be assessed by a number of disparate methods such as perceptual surveys and objective indices such as the size of the organisation and the complexity of systems. James and Jones believed that this approach was far too encompassing to be useful, with authors utilising this approach erroneously believing they were contributing something new to the literature when instead they were assessing what was more adequately described by other authors as components of situational variance or structure. James and Jones referred to the second approach as the perceptual measurements-organisational attribute approach, which regarded organisational climate as an attribute of an organisation, measured through the shared perceptions of employees. In contrast, the perceptual measurement-individual attribute approach regards climate as an attribute of the individual, not of a workgroup or organisation. Hence, data is not aggregated and analyses predict individual behaviour rather than that of a workgroup or organisation. These conceptual and methodological differences between the two approaches led James and Jones to suggest the rebranding of organisational climate assessed using the perceptual measurement-individual attribute approach as 'psychological climate'.

Though James and Jones' (1974) review made a significant contribution to the literature, with many authors adhering to their suggestions and using the term 'psychological climate', a great deal of confusion still remained. Glick (1985), in his review of the climate literature a decade later, bemoaned the fact that many authors had aggregated measures of psychological climate to make inferences about psychological climate, despite the unit of theory for psychological climate being the individual, not the aggregate. This problem was widespread and not limited to the time period of Glick's review, with a recent review by Kuenzi and Schminke (2009) finding over 100 articles that purported to measure organisational climate despite the unit of analysis being the individual, and therefore psychological climate being measured.

Further adding to the complexity of climate research was the lack of consensus over dimensionality. Since climate, both organisational and psychological, was considered a multidimensional 'umbrella' construct describing employees' perceptions of their environment, a large number of dimensions have been used to measure it. For example, Koys and DeCotiis (1991) identified over 80 distinct dimensions in their review of the psychological climate literature. The ever increasing number of dimensions posited by researchers was roundly criticised by Schneider (2000, p. 5), who lamented the tendency for researchers to add dimensions without theoretical rationale, stating that "climate research has languished as an increasingly large number of dimensions were added to its conceptualization, with new facets added each time a researcher thought climate might be useful for understanding some interesting phenomenon". Glick (1985) described climate's multidimensional nature as both an asset and a liability, as a multidimensional approach was required to capture multifaceted relationship between an individual and the organisation; however it also resulted in climate lacking parsimony. Glick (p. 606) stated "Saying everything is related to everything does not provide much of an explanation", a concern echoed by many authors including Guldenmund (2000), over a decade later, when he stated that the broad nature of climate had the potential to make it meaningless.

Another major hurdle facing climate research was the confusion over the conceptual boundaries between organisational climate and the related term of organisational culture (Kuenzi & Schminke, 2009). In his review of the literature, Schneider (2000) pointed out how some authors fostered confusion by using the terms interchangeably, despite there being a number of distinct differences between them. Though both terms refer to the process in which individuals make sense of their environment, safety culture, with its anthropological academic roots, seeks to understand the deeper, underlying assumptions and normative beliefs of the organisation (Schein, 2004). In comparison, climate refers to surface-level perceptions (Kuenzi & Schminke), and due to this lower level of abstraction it is argued that it can be readily assessed via quantitative measures such as perceptual surveys. To access these implicit and unconscious beliefs that constitute culture, qualitative methods are required, such as observation and interviews (Guldenmund, 2000).

The inconsistency in the use of the terms ‘climate’ and ‘culture’ in the literature is not surprising. Both concepts have changed markedly in the past few decades and refer to different things compared to early stages of research. Guldenmund (2000), for example, states that what was once considered organisational climate, as in, a broad multidimensional construct attributable to the organisation, now refers to the concept of organisational culture. Some authors have even revised their own conceptualisations of climate over the years. According to James and Jones’s (1974) conceptualisation of climate, organisational climate is an attribute of the organisation while psychological climate is an attribute of the individual. However, in later years James (James, 1982; James et. al., 2008) argued that organisational climate was simply the label for psychological climate when it was aggregated, the perceptions still being attributed to the individual regardless of whether psychological or organisational climate was measured. Despite organisational climate referring to shared perceptions and assessing the overall meaning employees derive from their environment (James, 1982; Schneider, 1983), James believes that the definition of the construct remains the same whether aggregated or not. However, most authors do not take this stance, with many considering organisational climate an attribute of the workgroup (e.g. Schneider & Reichers, 1983; Young & Parker, 1999), while others consider it an attribute of the organisation. Those authors whose focus is on the workgroup have what is known as a subjective perspective (Glick, 1988), whereby employee interactions in response to organisational phenomena leads to shared understanding and perceptions of these events. Those authors who consider climate an organisational attribute have what is known as an objective perspective (Glick, 1985; Rousseau, 1988), and assess employee descriptions of a specific area of organisational functioning such as customer service (Schneider & Bowen, 1985; Salvaggio et. al., 2007), ethics (Dickson, Smith, Grojean, & Ehrhart, 2001; Parboteeah & Kapp, 2008), diversity (McKay, Avery, & Morris, 2009), or safety (e.g. Zohar, 1980; Neal, Griffin, & Hart, 2000; Cooper & Phillips, 2004; Johnson, 2007). The latter - safety climate - is the focus of the current thesis, and as will be discussed shortly, has involved some researchers unifying both the subjective and objective approaches.

2.2 Safety Climate

The concept of safety climate was introduced by Zohar (1980, p. 96) to describe a specific type of organisational climate that “reflects employees’ perceptions about the relative importance of safe conduct in their organizational behaviour”. Research into facet specific forms of organisational climate were burgeoning at this time, in line with Schneider’s (1975) suggestion to focus on specific strategic areas of the organisation so as to improve the validity of climate instruments and avoid the definitional, theoretical and methodological confusion afflicting the organisational climate literature. In the following sections, the safety climate literature will be discussed, with attention directed at its definition, dimensionality, and relationship with other constructs.

2.3 Definition

One area where there appears to be general consensus in the literature is in the definition of safety climate. A comprehensive review by Guldenmund (2000) showed that most authors stressed the perceptual nature of safety climate (e.g. Zohar, 1980; Brown & Holmes, 1986; Glennon, 1982; Niskanen, 1994), with these perceptions being shared (e.g. Zohar, 1980; Brown & Holmes, 1986; Dedobbeleer and Beland, 1991; Diaz & Cabrera, 1997), and directed towards safety (e.g. Cooper & Phillips, 2004; Williamson, Feyer, Cairns, & Biancotti, 1997), organisational characteristics (e.g. Glennon, 1982), or the work environment (e.g. Zohar, 1980; Dedobeleer & Beland, 1991). A review of the definitions used in the past decade since Guldenmund’s review can be seen in Table 1.

Table 1

Definitions of Safety Climate

Reference	Definition of Safety Climate
Neal, Griffin, & Hart (2000)	“Safety climate is a specific form of organizational climate, which describes individual perceptions of the value of safety in the work environment” (p. 100)
Zohar (2000)	Perceptions of the overall priority of safety in regards to policies and procedures at the organisational level, and supervisory practices at the group level.
Gillen, Batlz, Gassel, Kirsch, & Vaccaro (2002)	“The Safety Climate Measure for Construction Sites analyzed worker perceptions of job safety regarding management concerns, safety activities, and employee risk” (p. 38)
Mearns, Flin, Gordon, & Fleming (2001)	“The study investigated the underlying structure and content of offshore employees’ attitudes to safety, feelings of safety and satisfaction with safety measures” (p. 144)
Mearns, Whitaker, & Flin (2003)	“…scales addressing satisfaction with safety activities, workforce involvement in health and safety planning, and communication about health and safety, as well as a set of 19 attitudinal statements about safety and 11 items relating to the frequency of unsafe behaviour” (p.646)
Silva, Lima, & Baptista (2004)	“Safety climate is understood as the shared perceptions about safety values, norms, beliefs, practices and procedures” (p. 211)
Cooper & Phillips (2004)	Safety climate describes shared employee perceptions of safety management, providing an indication of the overall priority of safety.
Seo, Torabi, Blair, & Ellis	Uses Zohar’s (1980, p. 96) definition of safety climate being a “summary of molar perceptions that

(2004)	employees share about their work environments”
Katz-Navon, Naveh, & Stern (2005)	Uses Schneider’s (1990, p. 384) definition of safety climate being “the shared perceptions of the employees concerning the practices, procedures, and the kind of behaviors that get rewarded, supported, and expected in a setting”
Zohar & Luria (2005)	“The core meaning of climate relates, therefore, to socially construed indications of desired role behavior, originating simultaneously from policy and procedural actions of top management and from supervisory actions exhibited by shop-floor or frontline supervisors” (p. 616) “…most climate scholars have postulated that safety climate perceptions refer to those attributes of policy and practice that indicate the priority of safety (which might diverge from formal declarations)” (p. 617)
Oliver, Tomas, & Cheyne (2006)	“Safety climate, the main focus of this study, refers to the shared perceptions of safety policies, procedures and practices*” (p. 29)* “Given that safety factors are inherent to any industrial process, and that they compete with other factors of the process, such as task speed or profitability, it is clear that safety policies and procedures have to be considered as relative priorities” (p.29)
Neal & Griffin (2006)	“The term *perceived safety climate,* therefore, refers to individual perceptions of policies, procedures, and practices relating to safety in the workplace. *Group safety climate* refers to the shared perceptions of the group as a whole” (pp. 946-947)

Hofmann & Mark (2006)	“Given the complexity of the health care delivery process, we believe that a comprehensive assessment of safety climate should assess not only the degree to which high-quality safety practices exist and the extent to which the social context encourages adherence to these policies. But, it should also include a focus on effectively and constructively responding to errors when they occur” (p. 849)
Wills, Watson, & Biggs (2006)	“This literature suggests SC (*safety climate*) represents employees' perceptions about organizational support, and particularly, management's commitment to safety in the organization” (p. 375)
Johnson (2007)	“Safety climate reflected employee perception of an organization's safety efforts” (p. 512). Johnson also uses Zohar and Luria’s definition of safety climate perceptions reflecting the priority safety is given in the organisation.
Hahn & Murphy (2008)	“Safety climate refers to shared perceptions of employees about the safety of their work environment” (p. 1047)
Baek, Bae, Ham, & Singh (2008)	Scale includes factors assessing management commitment to safety, merits of the H&S procedures, instructions, and rules, accidents and near misses, training and competence, job security and satisfaction, pressure for production, communications, perceptions of personal involvement in H&S, perceptions of organisational and management to H&S, rule breaking, workforce view on state of safety and culture.

Huang, Chen, DeArmond, Cigularov & Chen (2007)	"…safety climate is defined as employees' shared perceptions of the safety policies, procedures, and practices, as well as the overall importance and the true priority of safety at work" (p. 1089)
Matsubara, Hagihara, & Nobutomo (2008)	"The safety climate is conceptualized as workers' shared perceptions of how safety management is implemented in their workplace" (p. 211)
Neitzel, Seixas, Harris, & Camp (2008)	"This term refers to employees' shared perception of the priority safety receives in their workplace" (p. 392)
Newman, Griffin, & Mason (2008)	*"Safety climate* has been described as an individual's perceptions of the value and importance associated with safety within an organization" (p. 634)
Nielsen, Rasmussen, Glasscock, & Spangenberg (2008)	Refers to Zohar (2000), stating that Zohar "defines safety climate as employees' shared perceptions of management's commitment and performance with regards to safety policies, procedures and practices" (p. 440)
Pousette, Larsson, & Torner (2008)	Perceptions of safety conditions.
Probst, Brubaker, Barsotti (2008)	Uses definition by Zohar (1980, p. 101) of safety climate as a "unified set of cognitions [held by workers] regarding the safety aspects of their organization"
Strahan, Watson, Lennon (2008)	"Safety climate typically refers to workers' perceptions of the way in which the organisation views and manages safety" (p. 420)

Tharaldsen, Olsen, & Rundmo (2008)	“Safety climate, on the other hand, is often used to describe employees’ perceptions, attitudes and beliefs about risk and safety” (p. 428)
Turnberg & Daniell (2008)	Uses Zohar’s (1980, p. 96) definition of safety climate being a “summary of molar perceptions that employees share about their work environments”
Vinodkumar & Bhasi (2009)	“Safety climate can be defined as employees’ shared perceptions of safety policies, procedures, practices, as well as the overall importance and the true priority of safety at work (p. 659)
Christian, Bradley, Wallace, & Burke (2009)	“…shared perceptions of work environment characteristics as they pertain to safety matters that affect a group of individuals” (p. 1106)
Beus, Payne, Bergmann, & Arthur (2010)	“…employees’ perceptions of organizational safety policies, procedures, and practices” (p. 713)
Lu & Tsai (2010)	“…employees’ perceptions pertaining to safety practices, policies, and procedures, which are implemented and prioritized in the organization” (p. 2000)
Luria & Yagil (2010)	“…perceptions of policies, procedures, and practices concerning safety in organisations” (p. 1423)
Hansen Williams, & Singer (2010)	“Underlying safety culture visibly manifests itself in organizations as elements of safety climate, including policies, procedures, and practices, which can be more easily measured through workforce perceptions” (p. 598)
Lu & Yang (2011)	Refers to Zohar (1980), and states that “safety climate is a term used to describe shared employee perceptions of how safety management is being operationalized in the workplace” (p. 329).

From Table 1 it can clearly be seen that safety climate research has flourished over the past decade. Guldenmund (2000) listed 18 studies in his review of studies from 1980 to 1997, while it can be seen that there are 33 studies published from 2000 to 2011. The definitions demonstrate a high degree of consensus in the literature, with the majority of authors stating that safety climate consisted of "shared" or "molar" perceptions. Some authors associate safety climate with attitudes, beliefs, and satisfaction (e.g. Mearns, Flin, Gordon & Fleming, 2001; Mearns, Whitaker, & Flin, 2003; Tharaldsen, Olsen, & Rundmo, 2008; Baek, Bae, Ham, & Singh, 2008). However, as will be discussed later, attitudes and beliefs are more commonly considered to represent the related term of safety culture.

The objects of these perceptions vary considerably in their degree of explicitness, with authors using very general or implicit objects such as the safety management (Matsubara, Hagihara, & Nobutomo, 2008), work environment (e.g. Hahn & Murphy, 2008) safety conditions (e.g. Pousette, Larsson, & Torner, 2008) and the overall value/priority of safety in the workplace (e.g. Neitzel, Seixas, Harris, & Camp, 2008). A number of definitions are more explicit, referring to perceptions of policies, procedures and/or practices (Neal & Griffin, 2006; Zohar, 2000; Zohar & Luria, 2005; Katz-Navon, Naveh, Stern, 2005; Oliver, Tomas, & Cheyne, 2006; Huang, Chen, DeArmond, Cigularov & Chen, 2007; Vinodkumar & Bhasi, 2009), with the majority of the aforementioned authors mentioning that these perceptions of policies, procedures, and/or practices provide an indication of the overall priority safety is afforded in the workplace. This is in line with Zohar's updated (2000, Zohar & Luria, 2005) conceptualisation of safety climate. Zohar clearly remains an influential figure in the safety climate literature, with most authors citing or quoting him in their definitions, however a number of authors (e.g. Lu & Yang, 2011; Seo, Torabi, Blair, & Ellis; Probst, Brubaker, & Barsotti, 2008; Turnberg & Daniell, 2008) refer to Zohar's 1980 conceptualisation of safety climate, despite the construct being significantly redefined since his original article. Given that a definition "…sets the stage for ensuing research, i.e. it is the basis for hypotheses, research paradigms and interpretations of the findings" (Guldenmund, 2000, p. 227), this thesis will adopt Zohar's recent definition of the construct. Safety climate therefore will refer to shared perceptions of the overall priority of safety, as evidenced through enacted policies, procedures, and practices (Zohar, 2000; 2003; Zohar & Luria, 2005).

2.4 Safety Climate and Safety Culture

Another area where historically there has been considerable confusion is in the boundaries separating safety climate and safety culture. The term "safety culture" originated from the International Atomic Energy Agency's (IAEA, 1986) enquiry into the Chernobyl nuclear disaster, where it was ascertained that safety culture rather than technical malfunctions were largely responsible for the meltdown. The term has been used in disaster inquiry reports for over 20 years to describe the combination of social, managerial, and organisational factors that led to various disasters (Glendon, Clarke, & McKenna, 2006). Despite this rich history, a unanimously agreed upon definition, either conceptually or operationally, has proven elusive (Guldenmund, 2000). A multitude of definitions have been proposed (for a review, refer to Choudhry, Fang, & Mohamed, 2007; Guldenmund, 2000), however, a prominent definition is that safety culture refers to "the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management" (Health and Safety Commission, 1993, p. 23). Another commonly cited definition of safety culture is that it constitutes "the attitudes, beliefs, perceptions, and values that employees share in relation to safety" (Cox & Cox, 1991, p. 93). Though definitions differ across studies, the general consensus is that safety culture is a multidimensional construct, shared by employees, which provides a frame of reference when it comes to safety within an organization – hence the potential for confusion with safety climate is quite evident, with many authors confusing the terms or using them interchangeably (Cox & Flin, 1998; Glendon & Stanton, 2000).

It is evident that the confusion over safety climate and culture paralleled that of the wider organisational climate/culture literature. The generally agreed differences between safety climate and culture also echoed that of the wider literature. While safety climate is predominately assessed via perceptual surveys, multiple methods are required to adequately assess safety culture due its complex multidimensional and multilayered nature (Glendon & Stanton, 2000). Triangulation is an approach advocated by a number of researchers (Cooper, 2000; Cox & Cheyne, 2000; Flin, Mearns, O'Connor, & Bryden, 2000; Glendon et al., 2006), and involves utilising a combination of methodologies (e.g. multiple sources of data, multiple method techniques, multiple data collection times) on the same object of study. For example, Cox and Cheyne (2000) utilised perceptual/attitudinal surveys, behavioural indicators, document analysis, and interviews/focus groups. The triangulation approach is useful as it counterbalances the limitations of any single approach (Glendon et al., 2006).

Safety climate and safety culture are generally perceived as being related yet distinct entities, with safety climate a measurable manifestation of safety culture (Choudhry et al., 2007; Cox & Flin, 1998) or a component of safety culture (Cooper & Phillips, 2004; Glendon & Stanton, 2000). Safety culture is often regarded as a more trait-like, complex and stable construct, whilst safety climate is seen as more state-like, a surface-level ‘snapshot’ indicative of selected aspects of the safety culture at a particular point in time (Cox & Cheyne, 2000; Glendon & Stanton, 2000). This relationship between safety culture and safety climate is perhaps best demonstrated by the many models used to describe safety culture. A similarity that exists in many of these models is that safety culture is comprised of a number of levels/layers. This perspective can be traced to Schein’s (1992) multi-layered organisational culture model. For example, Guldenmund (2000), drawing on the work of Schein (1992) and Cox and Cox (1991), described three layers of safety culture. The first is the outer layer, which consists of behaviour and visible artefacts such as meetings, inspection reports, and dress codes. This is the most overt manifestation of culture, but alone provides little insight into the comprehension of the underlying culture. The middle layer consists of relatively explicit and conscious values and attitudes, directed at hardware, software, people, and risks. Hardware refers to safety equipment and hazards while software refers to policies and procedures, and legislation. ’People’ refers to attitudes directed at fellow workers, supervisors, managers, and non-organisational entities such as unions and authorities. Finally, risks refer to risky behaviour and regulation. The core layer represents the implicit ontological assumptions that permeate the organisation. This deepest layer of culture is also the hardest to assess, and can be deduced through examination of the preceding layers and observation. Figure 1 summarises Guldenmund's model.

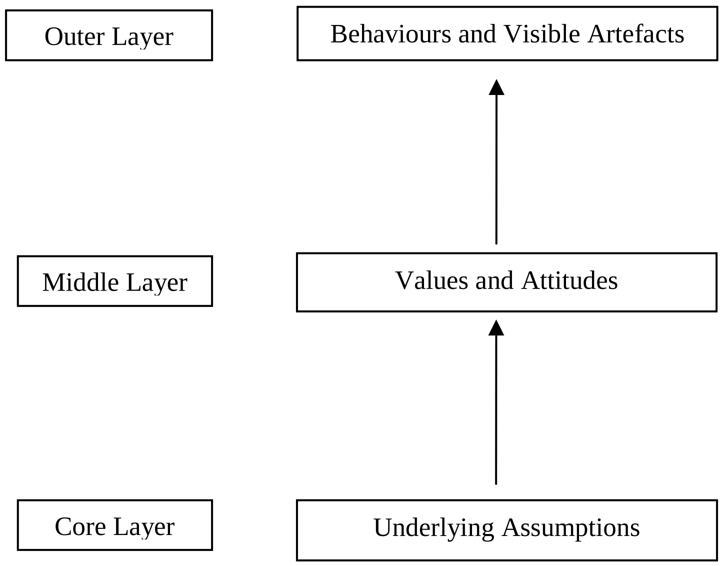

Figure 1. Representation of Guldenmund's (2000) safety culture model.

This model merged both safety climate and safety culture as the middle layer represented safety climate. Guldenmund stated that each layer may be studied separately, and so it can be seen that in this perspective safety climate is one manifestation of safety culture. In this model safety climate is assessed through attitudes. While operationalizing safety climate through attitudinal surveys makes safety climate fit neatly within the pre-existing culture literature, it also puts it at odds with the majority of safety climate literature which define it as consisting of perceptions (Zohar, 1980; Zohar & Luria, 2005; Brown & Holmes, 1986; Glennon, 1982; Niskanen, 1994; Neal & Griffin, 2006; Oliver, Tomas, & Cheyne, 2006; Hahn & Murphy, 2008; Christian et al., 2009; Johnson, 2007; Beus et al., 2010). Attitudes have long been considered distinct from perceptions, with James and Jones (1979) noting that attitudes were of an emotional and evaluative nature, with perceptions being of a cognitive and descriptive nature. While the distinction between attitudes and perceptions are not universally agreed upon, with Eagley and Chaiken (1982) describing attitudes as having cognitive, behavioural and affective components, the vast majority of authors (and the current thesis) takes the view that attitudes do not represent safety climate due to their affective and evaluative nature. Therefore, the attitudes-based conceptualisation of safety climate is a limitation of Guldenmund's model, particularly in light of recent research which has supported the empirical distinctiveness of safety climate and attitudes (Pousette et al., 2008).

Glendon and Stanton (2000) similarly take this three layered approach, yet include two additional dimensions. Their significantly more complex model (as seen in Figure 2) notes the importance of breadth (how localised or shared the cultural elements are across the organisation) and time (as cultural elements do not exist at one point at time – they also have a past and future).

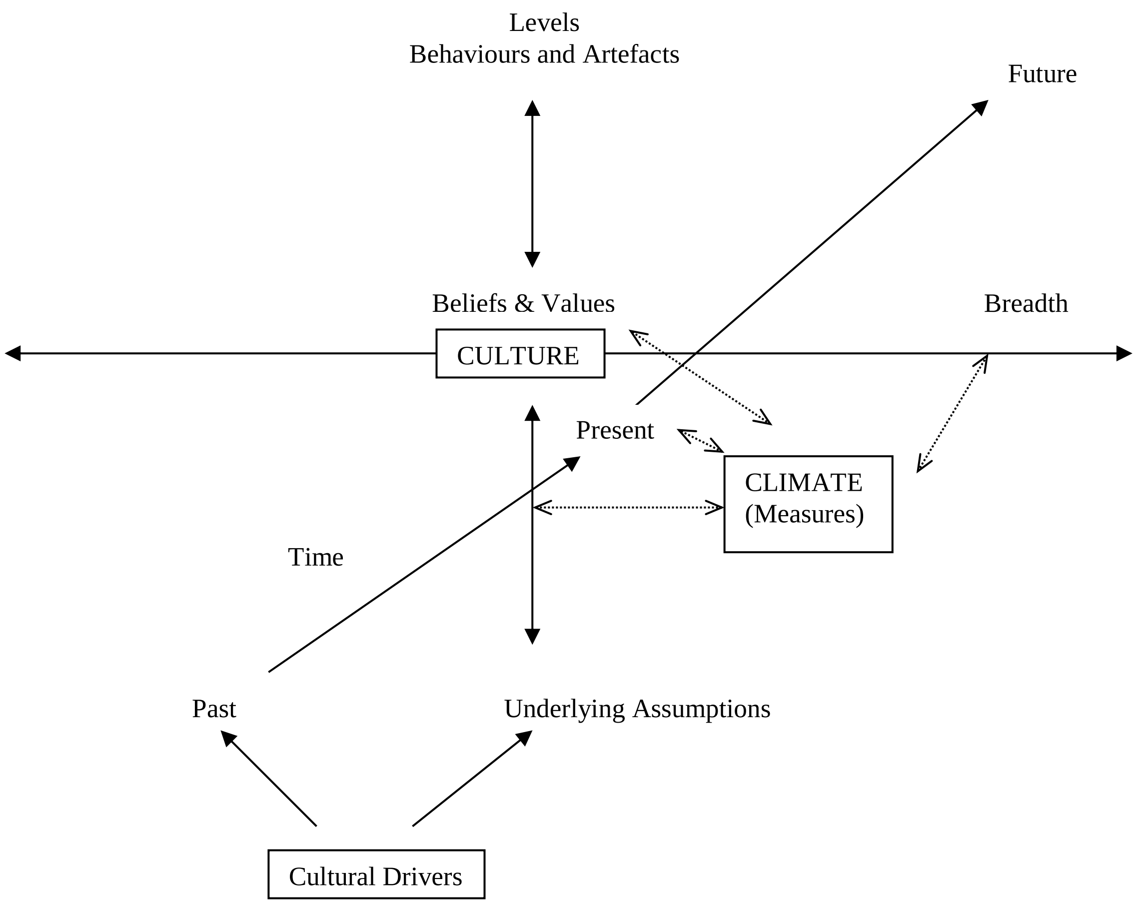

Figure 2. Glendon and Stanton's (2000, p. 199) model describing the relationship between culture and climate.

Like Guldenmund, Glendon and Stanton place climate in the middle layer of the three-layer model, and since climate measures only some aspects of culture at a particular time, it provides only a superficial indication of culture (Glendon & Stanton, 2000). Additionally, Glendon and Stanton's model describes the layers of safety culture affecting one another in both directions, contrasting with Guldenmund's linear representation of culture. This linearity, in which implicit assumptions dictate attitudes, which in turn dictate behaviour, was the subject of criticism by Cooper (2000). Cooper (2000) stated that the model was overly linear, as behaviours have been demonstrated to affect attitudes and not just be dictated by them. It could also be argued that assessing the deeper layers in Guldenmund and Glendon and Stanton's model is extremely difficult, given they consist of implicit underlying assumptions. Though Glendon and Stanton's model more comprehensively describes the elements of culture within an organisation, it also makes the measurement of culture much more complex and time consuming. Glendon and Stanton note that additional dimensions are likely, but are difficult to represent on a two-dimensional figure. Hence, while Glendon and Stanton's addition of a time and breadth dimension theoretically extends the culture construct, their conceptualisation is potentially even more difficult for organisations to assess than Guldenmund's model.

Cooper's (2000) model shares some similarities with those previously described. In his reciprocal model based on Bandura's (1977) social learning theory, safety culture is the result of an interaction between person, behaviour, and the situation, as seen in Figure 3. Situational features of the organisation include policies, practices, and procedures, in other words, the safety management system. The behavioural component consists of observable safety-related behaviours. The person component is safety climate; hence it is subjective psychological factors such as perceptions. Unlike the previous models, safety climate is represented as a component of safety culture. Another major difference is that unlike Guldenmund's linear model, Cooper's reciprocal safety culture specifies a dynamic relationship present between components, with each component interrelated with the other two. A strength of this model compared to previous models is that each component is clearly operationalized and relatively simple to assess. However, the three-way interactions between the components have not been empirically tested (Glendon et al., 2006).

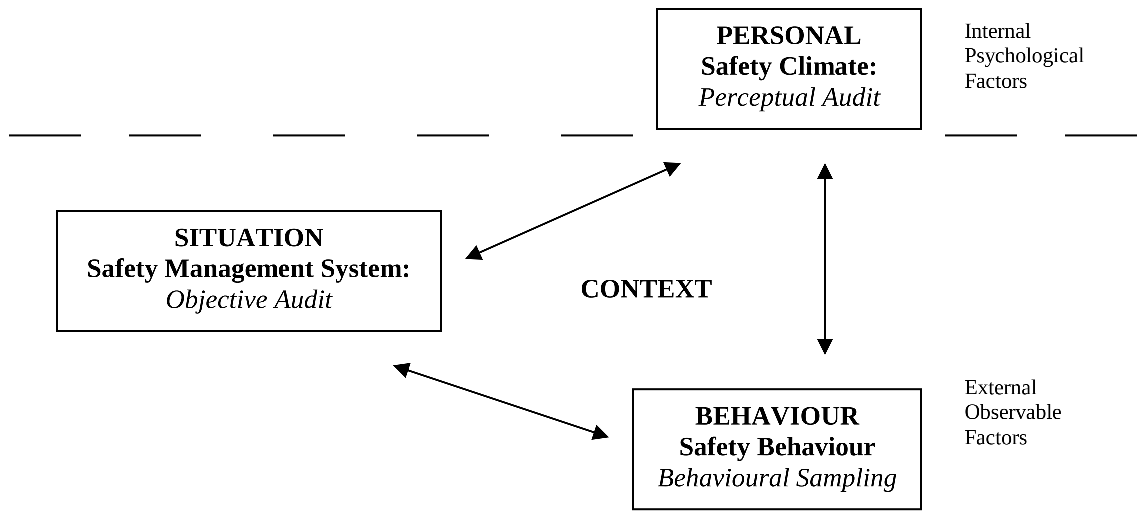

Figure 3. Cooper's (2000, p. 120) reciprocal safety culture model.

In summary, there are a number of models of safety culture, each catering towards a different definition, approach and metatheoretical underpinning. All models are somewhat similar in their representation of safety culture, as all emphasise safety culture's complex, multifaceted nature. Though there are some differences between the models in their operationalisation of safety culture and their emphasis on specific aspects, in all models safety culture is seen to be reflected in situational/environmental features, internal psychological factors (i.e. safety climate), and behaviour.

2.5 Models of Safety Climate

A major contributor to safety climate's lack of conceptual development for a number of years had been the lack of a causal model or theoretical framework to guide research. In Guldenmund's (2000) review he regretted that few authors attempted to relate their study to previous research or tried to establish an integrative framework, with most authors simply developing new scales from scratch. However, much has changed in a decade, with a number of detailed models emerging shortly after the publication of Guldenmund's review.

2.5.1 Zohar's Multilevel Model of Safety Climate

One of the models was developed by Zohar (2000; 2003; Zohar & Luria, 2005), the researcher responsible for introducing the term 'safety climate'. Compared to his original conceptualisation of the construct, his recent model is far more detailed in describing the processes by which safety climate affects safety outcomes. According to Zohar's Multilevel Model of Safety Climate, safety climate derives from shared perceptions of an organisation's priority for safety, relative to other production goals (i.e. pressure to work speedily). These perceptions are not of formal policy (e.g. written procedures) but of enacted policies, the actions which management take in reality, which may contrast with formal policies (e.g. management expecting employees to disregard certain procedures if production is falling behind schedule). From these perceptions of safety's true priority, employees develop behaviour-outcome expectancies, in other words, they can hypothesise the consequences of their safety-related actions. For example, if from previous events employees perceive production speed is rewarded; it is more likely that employees will prioritise speed over safety due to the expectancy of reward. This aspect of Zohar's theory integrates the findings of a number of influential researchers in the behaviour literature, with these expectancies shown to be the strongest predictor of behaviour in a number of studies (e.g. Bandura, 1986; Lawler, 1971; Vroom, 1964, Ramsey et. al., 2000). Overall, employees should more frequently exhibit safe behaviour if safety has a high priority, and since human action is a primary determinant of injury (Reason, 1990; 1997; McAfee & Winn, 1989; Fellner & Sulzer-Azaroff, 1984), injury rates should be lower in environments with a positive safety climate. Safety climate's ability to predict safety behaviour (e.g. Cooper & Phillips, 2004, Johnson, 2007) and injury rate (e.g. Zohar, 2000; Hoffman & Mark, 2006) therefore reflects this aspect of Zohar's theory.

As the name of Zohar's model suggests, the multilevel aspect of safety climate is also highly important. While conventional safety climate measures include items relating to both supervisors and manager commitment to safety in the one scale (e.g. Seo et al., 2004, Mearns, Whitaker, & Flin, 2003; Tharaldsen, Olsen, & Rundmo, 2008), doing this fails to reflect theory and empirical evidence demonstrating that managers and supervisors contribute to safety outcomes in different ways (e.g. Simard & Marchand, 1997; Tomas, Melia, & Oliver, 1999). According to Zohar's model, supervisors have discretion in their implementation of management policy, therefore potentially creating a discrepancy between formal and enacted policy. This discretion stems from the fact that formal policies would unlikely cover every possible eventuality, and that production pressures may result in a different interpretation and implementation of formal policies depending on the supervisor. For example, if employees in a particular workgroup perceive that their supervisor promotes the cutting of corners when production is falling behind schedule, then a safety climate may be formed which is distinct from other workgroups and from the overall organisational safety climate. Hence, employees will have coexisting safety climate perceptions, directed towards multiple levels of the organisation's hierarchy. This aspect of Zohar's theory has also been supported by empirical evidence, with Zohar and Luria (2005) finding variation between workgroups in terms of perceptions of supervisors (group-level safety climate), with group-level safety climate meditating the relationship between perceptions of managers (organisational level safety climate) and safety audit scores. More recent research by Zohar and Luria (2010) found that supervisors can act as 'gatekeepers', protecting against harmful management level safety climates. Zohar also postulated that his model could be extended to include additional levels of the organisation, since each level has discretion in conveying the priority of safety to the level below them. Hence, mid-level management may potentially be a source of behaviour-outcome expectancies, though this aspect of his theory has not yet been tested.

A primary advantage of separating the perceptions of supervisors and managers is that it provides more specific and practicable feedback to the organisation -

interventions can be directed towards supervisors or managers since they would be measured by separate scales with separate scores. This practicality is further improved by the behaviour-based itemisation used by Zohar. Rather than having items which generically refer to commitment to safety in his scales, Zohar refers to specific behaviours relating to active, proactive, and declarative practices for each level of the organisation. Active practices refer to monitoring and control behaviours, proactive practices refer to the promotion of learning and improvement, and declarative practices refer to public declarations. Active and proactive practices are synonymous with the variables of safety compliance and safety participation (Griffin & Neal, 2000), and control versus commitment (Zacharatos, Barling, & Iverson, 2005).

Since perceptions are shared within a workgroup for perceptions of supervisors and across the organisation for perceptions of managers, data would need to be aggregated to reflect these shared perceptions (within group homogeneity and between group heterogeneity needs to be demonstrated before this occurs). The shared nature of safety climate has been statistically tested and demonstrated in a number of studies (e.g. Zohar, 2000; Oliver, Tomas, & Cheyne, 2006; Pousette et al., 2008). Aggregating the data and conducting multi-level analyses in this manner also makes analytical sense. Since safety climate consists of shared perceptions, using standard statistical techniques would not be appropriate given that they assume independence of observations (Kreft & De Leeuw, 1998). The basic premise of multi-level analysis is that it takes into account this dependency of observations in groups (Twisk, 2006).

In recent articles Zohar (2008; 2010) has further elaborated upon his model, detailing the potential social-cognitive processes which precede the formation of safety climate perceptions. One process is symbolic social interaction, which refers to how individuals construct reality by comparing their own perceptions of events with those around them (Blumer, 1969; Stryker, 2008). Zohar (2010, p. 1519) states that the process involves "…comparing bits of information and cues, discussing possible interpretations, and attempting to reach consensual interpretation of the meaning of events, procedures and practices at the workplace", which over time results in the convergence of perceptions. It is suggested that these shared meanings promote the emergence of shared climate perceptions, particularly at the group level since employees would likely interact more with those in the same workgroup (Zohar, 2010). The role of these symbolic interactions in forming safety climate perceptions was examined by Zohar and Tenne-Gazit (2008), who used a social-network analysis to find that the density of group communication (a proxy for the symbolic interaction sense-making process) was positively related to the level of consensus in climate perceptions (climate strength). Their results echoed that of other researchers who examined the role of symbolic interaction in predicting climate strength in the wider organisational climate literature (Gonzalez-Roma, Peiro, & Tordera, 2002; Klein, Conn, Smith, & Sorra, 2001). Given that safety climate was considered to reflect the 'objective' approach to organisational climate (Parker et al., 2003), by including social-cognitive processes, Zohar has incorporated the 'subjective' approach to organisational climate in his theoretical framework.

A related potential antecedent of safety climate is leadership, a premise dating back to Lewin and colleague's (1939) study examining leader-created climates in a summer camp context. As previously explained, employees observe and interact with supervisors and managers, informing them of the relative priority of safety within the organisation. A proximal antecedent of climate is the quality of the interactions between leaders and employees (Hoffman & Morgeson, 2003; Ostroff, Kinicki, & Tamkins, 2003), assessed through such constructs as transformational leadership (Bass, 1990; Zohar& Luria, 2010) and leader-member exchange (Graen & Uhl-Bien, 1995; Zohar & Luria, 2005). Zohar and Luria (2010) differentiates between leadership and safety climate by stating that leadership is the medium in which safety's priority is demonstrated, and that higher quality leadership interactions promote stronger climates; however they are distinct constructs which are assessed in a different manner. Safety climate is assessed via surveys enquiring about commitment to safety, while leadership is assessed via surveys enquiring about the nature of exchanges and the quality of the relationship. The quality of leadership interactions is suggested to be a product of the leader's care and concern for employee welfare, growth, and development (Hoffman & Morgeson, 2003; Zohar, 2003; Zohar & Luria, 2010). Zohar and Luria (2010) states that leaders who care about their employees will have higher quality interactions, with these higher quality interactions providing the opportunity for safety related information to be communicated. Hence, safety climate perceptions develop through a combination of leader-member exchanges (leadership) and member-member exchanges (symbolic social interaction) (Zohar, 2010).

Zohar (2010) recently proposed a model which includes the previously mentioned antecedents of safety climate (see Figure 4). The model modifies and extends upon Reason's (1997) safety pyramid model, depicting the relationship between a number of organisational variables and safety outcomes. The bottom layer of the pyramid represents the organisational policies, practices, and procedures, and the extent to which they reflect a priority for safety (i.e. management commitment to safety). A distinction is made between espoused and enacted priorities, given that management might contradict their espoused policies when competing demands (e.g. time, cost) come to the fore. The middle layer is supervisor commitment to safety, hence the group or departmental safety priority over other factors such as production pressure. These levels of safety climate promote unsafe behaviour and are also 'latent pathogens', in other words, factors which contribute to an overall unsafe working environment and increase the probability of employees becoming injured.

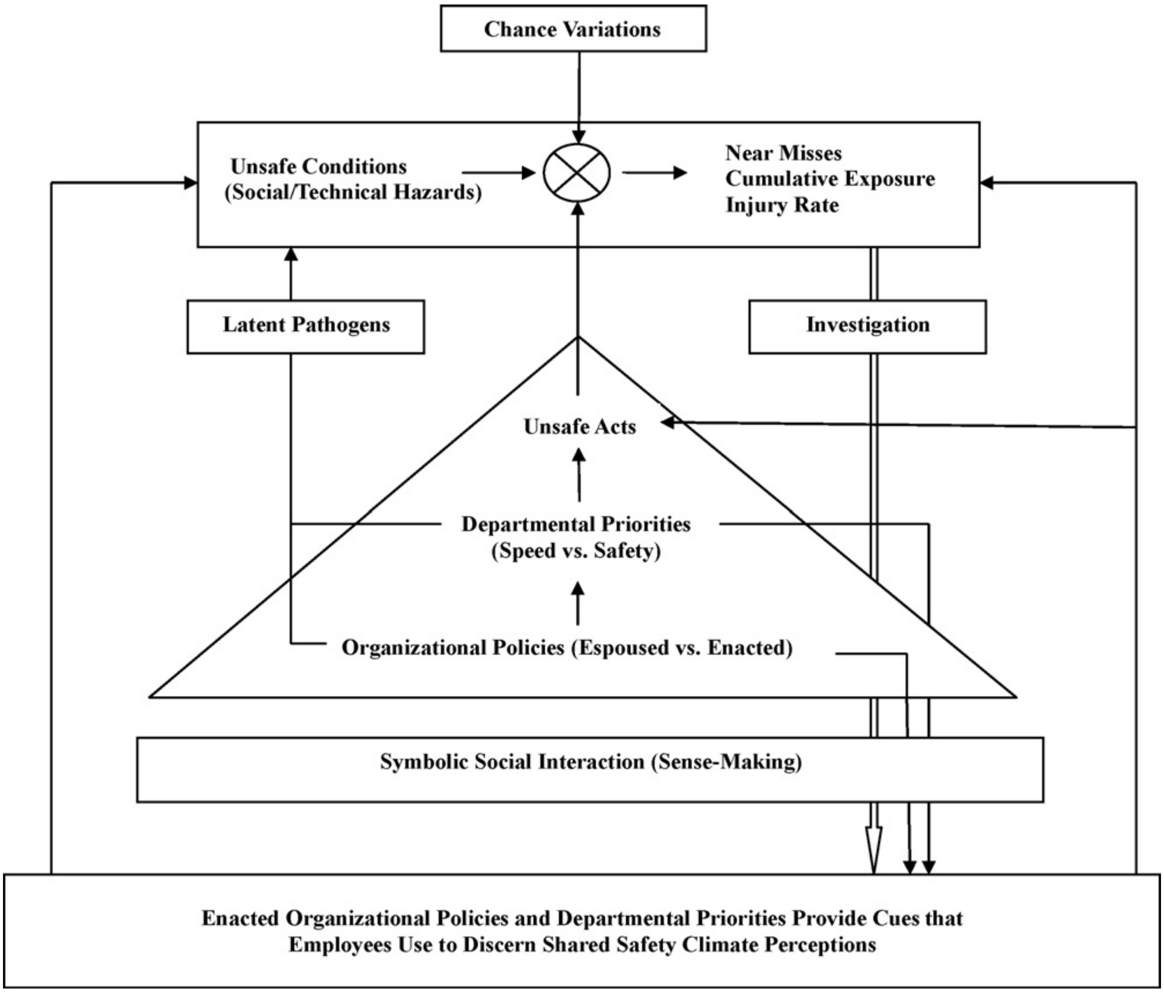

Figure 4. Zohar's (2010, p. 1520) safety pyramid model.

2.5.2 Griffin and Neal's Model

At approximately the same time as Zohar, Griffin and Neal (2000; Neal, Griffin, & Hart, 2000) proposed their own safety climate model. Griffin and Neal acknowledged the lack of a cohesive framework linking safety climate to behaviour and so tested the model seen in Figure 5, with a similar model tested by Neal, Griffin, and Hart.

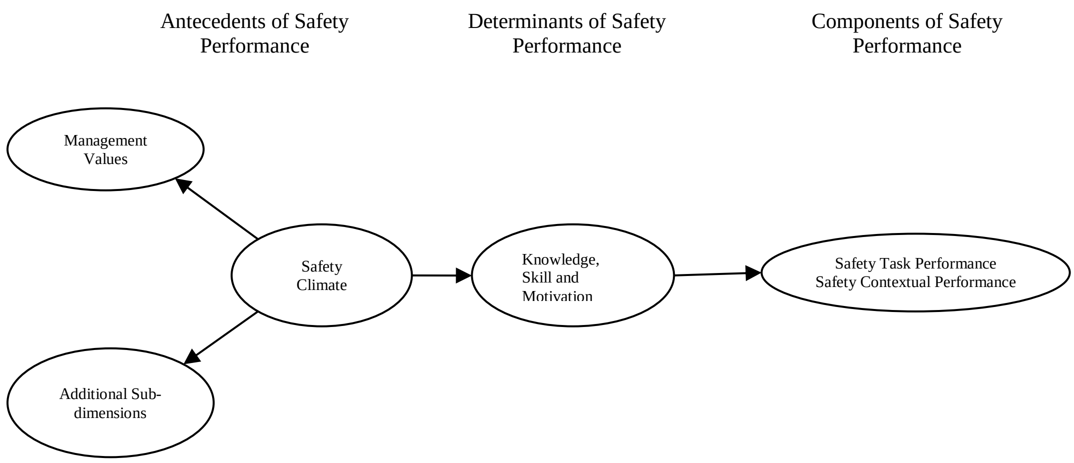

Figure 5. Griffin and Neal’s (2000, p. 349) safety climate model.

In order to more comprehensively describe the mechanisms in which safety climate affected safety performance, Griffin and Neal included the components, determinants, and antecedents of performance. Based on the work of Motowidlo and Van Scotter (1994), the components of safety performance included task performance, which assessed compliance to safety rules and regulations, and contextual performance, which assessed participation and organisational citizenship behaviours related to safety. Griffin and Neal referred to these components as safety compliance and safety participation respectively. The determinants of safety performance included knowledge and motivation. Hence, unlike Zohar’s model which had safety climate directly predicting safety outcomes, Griffin and Neal’s model proposes that this relationship is mediated. This belief was based on the work of Campbell, McCloy, Oppler, and Sager (1993), and posits that an individual must understand how to work safely and be motivated to perform for safe behaviour to occur. Support for this model was found in Griffin and Neal (2000) and Neal, Griffin, and Hart (2000), with the latter study additionally finding support for a model with organisational climate as an antecedent of safety climate. Since organisational climate generally refers to the quality of the work environment and the support provided to employees, this model suggests that organisations that support their employees tend to be supportive of safety too. Neal, Griffin and Hart suggested that interventions directed at improving an organisation's safety climate will likely be more effective if it is part of an overall organisational climate improvement program. Zohar (2008) alternatively does not place as much importance in organisational climate, preferring facet specific climates given they are less generic and ambiguous than organisational climate. Instead, Zohar (2008) proposed that employees develop perceptions of multiple facet specific climates (e.g. safety, creativity, ethics) instead of a global organisational climate. The number of facets that employees attend to is limited, given the complexity of the organisational environment and the social-cognitive processes that lead to shared perceptions, (Hardins & Higgin, 1995; Schneider & Reichers, 1983). Hence, Zohar (2008) suggested that employees focus on those climates that best predict the outcomes of behaviour. While this move away from organisational climate to multiple facet specific climates hold promise, there has been little subsequent research investigating Zohar's multiple climate framework.

Griffin and Neal's theory, which outlined the antecedents, determinants and components of safety performance, was a positive step forward in clearly operationalizing and defining the variables which predict and are predicted by safety climate. While these early studies were conducted at the individual level, subsequent testing of this mediated relationship between aggregated safety climate scores and safety outcomes found support for the model. Neal and Griffin (2006) conducted a five year longitudinal examination of the relationship safety climate had with safety outcomes in the healthcare context. While safety climate did not directly predict safety behaviour, it did predict safety motivation which in turn predicted behaviour. Safety climate in this study was aggregated to the group level, and so there was stronger evidence for the findings being generalizable to the wider literature.

Theoretically, Zohar and Griffin and Neal's model have some key differences, with these differences even more evident when discussing their methodology. As previously stated, Zohar adhered to a multi-level model of safety climate, where perceptions of supervisors and managers were separated and aggregated to their respective levels. In contrast, Neal and Griffin appear to follow a single-level model of safety climate, with management commitment to safety being the unidimensional target of perceptions. Supervisors appear to have little role in the promotion of safety, or are considered indistinct from management. Additionally, the wording of items is extremely different. In Zohar's recent studies, a behaviour-based operationalization is used, with items such as "Provides all the equipment to do the job safely" and "Listens carefully to workers' ideas about improving safety" (Zohar & Luria, 2005, p. 628). Neal and Griffin (2006, p. 953) alternatively do not address specific behaviours, with their 3-item scale consisting of different rewordings of "Management considers safety to be important". Safety compliance and safety participation, which are the two outcome variables in Neal and Griffin's study, are actually two subscales in Zohar's safety climate scales. Zohar labels safety compliance and safety participation as "active" and "proactive" practices respectively. Finally, Neal and Griffin's scale was aggregated to the group level despite group practices not being assessed, a limitation that Neal and Griffin acknowledge as potentially reducing the sensitivity of the scale. Hence, there are substantial methodological differences between these two approaches to safety climate, which may explain the differences in findings. While Zohar (2000) acknowledges that behaviour-outcome expectancies have a motivating effect, it is strangely never tested in his studies. No study has yet determined whether the relationship between safety climate and safety outcomes is mediated by individual variables such as motivation and knowledge while using a behaviour-based multilevel operationalization of the construct. Therefore, while there are substantial differences between these models, there is the possibility that they can be integrated into a singular model, as seen in Flin's (2007) safety climate model.

2.5.3 Flin's Safety Climate Model

Flin (2007) has recently attempted to combine the different approaches of Griffin and Neal and Zohar by proposing a safety climate model for the healthcare context, as seen in Figure 6. In Flin's model, safety climate consists of manager and supervisor commitment to safety, aggregated to the workgroup and organisation as per Zohar's Multilevel Model of Safety Climate. Hence, this model acknowledges a multilevel operationalization of safety climate and expands upon Griffin and Neal's model which focused solely on management. In the model, safety climate determines an individual's motivation/behaviour-outcome expectations, which in inturn affects safety behaviour, such as an individual's compliance with safety rules and their participation in safety related endeavours. While Zohar and Neal and Griffin describe a somewhat different intervening variable between safety climate and safety behaviour (behaviour-outcome expectancies versus motivation), Flin suggests that the two models are congruent with one another, as both intervening variables describe a motivational driver which directs behaviour. Though the intervening variable in Zohar's model is not explicitly measured, in Neal and Griffin's and Flin's model motivation is assessed, reflecting the mediation findings of Griffin and Neal (2000) and Neal and Griffin (2006).

One aspect of Flin's model which separates it from Zohar's model is the addition of human error as a separate stage. Flin states that a drawback of Zohar's model is that he fails to specify how behaviour-outcome expectancies lead to errors. In other words, while behaviour-outcome expectancies might explain why an employee might rush a task or not wear proper safety equipment, it does not explain why an employee might misread procedures for example. Hence, errors in Flin's model are included as a separate stage to illustrate how unsafe behaviours have a tendency to result in errors. The presence of errors is particularly relevant for the healthcare context where Flin directed her model, given that an error (e.g. administering the wrong dosage of medication) would have immediate and potentially fatal outcomes.

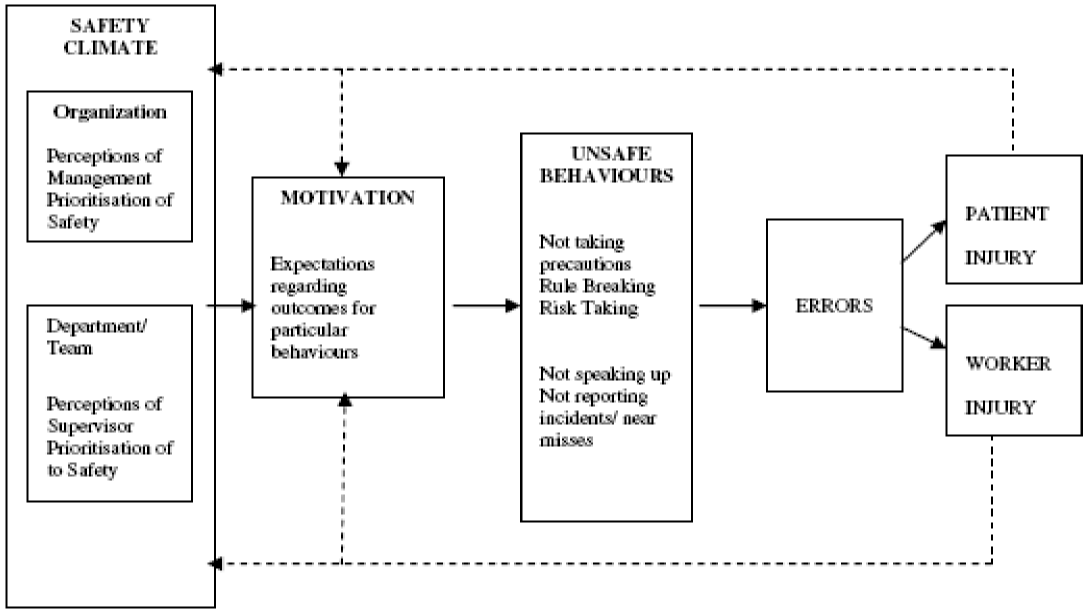

Figure 6. Flin's (2007, p. 660) model of safety climate for the healthcare context.

While not explicitly modelled, error may also be a consequence in Zohar's conceptualisation of the construct. According to Zohar and Luria (2005), if employees perceive that speed is unequivocally prioritised over safety, their behaviour will reflect these priorities. Hence, it is reasonable to assume that errors will result from such a speed-orientated safety climate, despite not being mentioned in his studies. Conversely, in Zohar's (2010) Safety Pyramid model, there are some organisational factors not included in Griffin and Neal's and Flin's models, such as unsafe conditions and chance variations. It is unlikely that Griffin and Neal and Flin are unaware of such factors, and so these minor differences between the models may represent differences in the priorities of the researchers.

Zohar's scales, with their behaviour-based itemisation, are tailor made for diagnosing specific vulnerabilities in an organisation. He additionally focuses on group/organisational predictor variables, and neglects individual predictors such as motivation and knowledge. It appears Zohar wants his research and scales to be of maximum practical use to organisations. Changing an organisation's safety climate or conditions would likely reduce the injury rate, while an individual's motivation would be less important to measure given it is largely a product of the organisation's safety climate. Alternatively, Neal and Griffin and Flin appear to be more interested in the individual mechanisms in which safety climate affects behaviour, with their models primarily consisting of individual variables rather than organisational/group level variables. Overall, the differences between these two perspectives are minor, and the absence of any variable in these models does not necessarily represent a limitation, but possibly differences in the goals of researchers.

2.5.4 Christian and Colleagues' Safety Climate Model

Another recent model of the factors contributing to safety outcomes was featured in a meta-analysis by Christian, Bradley, Wallace and Burke (2009). As seen in Figure 7, it is a fairly comprehensive model based once again upon Neal and Griffin's workplace safety model. Similarly to Neal and Griffin, Christian and colleagues do not represent safety climate as directly affecting safety outcomes, but rather model it as a distal link to safety outcomes in comparison to the more proximally linked safety motivation/safety knowledge. Christian and colleagues also included person-related factors such as personality characteristics and job attitudes, which were also modelled as distally related to safety climate. Meta-analysis of the literature supported their proposed model, with safety climate positively associated with safety knowledge and motivation. Personality (conscientiousness) was significantly associated with safety motivation. Safety motivation and knowledge in turn was significantly associated with safety performance (i.e. Neal and Griffin's safety compliance and safety participation), which was negatively associated with injuries and accidents.

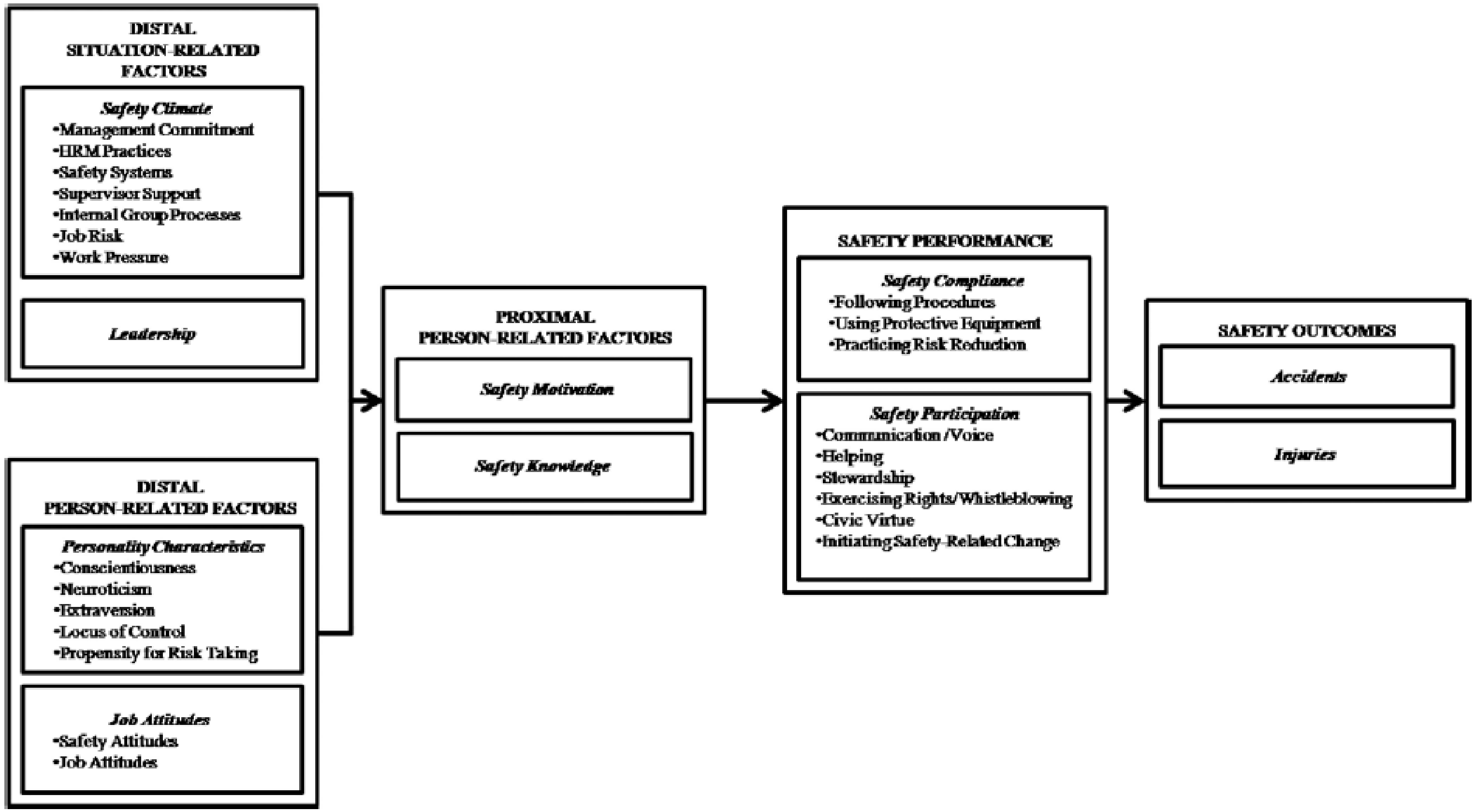

Figure 7. Christian and colleagues (2009, p. 1105) model of safety climate.

Though Christian and colleagues (2009) meta-analysis provided clarity and some much needed insight into the murky safety climate literature, cross-level effects were not included due to their potential to impair interpretation of results (see Ostroff & Harrison, 1999). Therefore, while the meta-analysis compared individual and aggregated data, it did not take into account research such as Zohar and Luria (2005) which demonstrated that organisational safety climate predicted group-level safety climate, which in turn was related to safety outcomes. Hence, in Christian and colleague's meta-analysis, management and supervisor commitment to safety was considered as being on the same level, despite research which has shown significant variation in group- level (supervisor) priorities within the one organisation (Zohar & Luria, 2005).

By mixing items related to group and organisational priorities in the one scale, scores will reflect an indeterminate mixture of levels, reducing measurement sensitivity and conceptual rigour (Zohar, 2008; 2010). For example, it would be far more informative for an organisation to determine whether perceptions of HRM practices or the safety system, two safety climate dimensions mentioned in Christian and colleague's model, were the product of group level or organisational priorities. Additionally, the model includes job risk as a dimension, which as discussed later, does not represent the construct of safety climate (Beus et. al, 2010).

Hence, while Christian and colleague's meta-analysis made a number of important contributions to the literature, some of aspects of it do not reflect recent advances in research. As seen in Zohar's model and Flin's model, it is important to separate perceptions of supervisors and managers for both practical and methodological reasons. It may not have been possible for Christian and colleagues to integrate cross-level effects in their meta-analysis, particularly given the small number of studies which perform such analyses; however cross-level effects do represent an important avenue of research given their previously mentioned advantages over traditional single-level safety climate methodology.

2.6 Methodological Implications

Given the substantial conceptual and methodological advances that have been made since Guldenmund (2000) published his review, it was investigated whether this has been reflected in the type and quality of research that has recently been conducted. Table 2 lists the scale used, the research goal, and the presence of aggregation in safety climate studies conducted in the past decade.

It is firstly evident the large number of distinct scales used to assess safety climate. Out of the 34 studies included in the review, there were 29 distinct safety climate scales. This suggests that there is not yet a generally accepted safety climate scale in any industry. Looking at the research goals of each study, it appears the literature is primarily concerned with methodological rather than theoretical issues, a finding echoed by Zohar (2010). Many of the studies are focused on scale development (Hahn & Murphy, 2008; Matsubara, Hagihara, & Nobutomo, 2008; Mearns, Flin, Gordon, & Fleming, 2001; Seo, Torabi, Blair, & Ellis, 2004; Silva, Lima, & Baptista, 2004; Tharaldsen, Olsen, & Rundmo, 2008; Vinodkumar & Bhasi, 2009) and predictive validity (Hansen, Williams, & Singer, 2010; Hoffman & Mark, 2006; Huang, Chen, DeArmond, Cigularov & Chen, 2007; Johnson, 2007; Katz-Navon, Naveh, & Stern, 2005; Lu & Tsai, 2010; Mearns, Whitaker, & Flin, 2003; Neitzel, Seixas, Harris, & Camp, 2008; Pousette, Larsson, & Torner, 2008; Probst, Brubaker, Barsotti, 2008; Strahan, Watson, Lennon, 2008; Wills, Watson, & Biggs, 2006). This represents substantial progress since Guldenmund published his review, where he lamented the lack of research investigating factorial or predictive validity, suggesting that the construct was still in an early developmental stage. Zohar (2010) states that the development and validation of new scales for specific contexts is something to be encouraged, as the target of climate perceptions may be context dependent. A context specific scale will likely be more sensitive than a scale generically enquiring about management/supervisor commitment to safety.

Table 2

Research Goals of Recent Safety Climate Articles

Reference	Source of Scale	Aggregated (Yes/No)	Goal/s
Neal, Griffin, & Hart (2000)	Self-developed.	No	1. Determine relationship between organisational climate and safety climate and their effect on safety performance.
Zohar (2000)	Self-developed.	Yes	1. Outline a new theoretical model of safety climate. 2. Develop and validate scale for assessing group-level safety climate. 3. Test model by examining relationship between group-level safety climate and micro-accidents.
Gillen, Batlz, Gassel, Kirsch, & Vaccaro (2002)	Dedobbeleer and Beland (1991)	No	1. Determine contribution of safety climate, job demands, decision latitude, and co-worker support on injury severity.
Mearns, Flin, Gordon, & Fleming (2001)	Scales taken from Offshore Risk Perception Questionnaire (Flin, Mearns, Fleming, & Gordon, 1996a; 1996b) and additions made.	No	1. Develop and validate safety climate survey. 2. Examine relationship between survey, safety behaviour and accidents.

Mearns, Whitaker, & Flin (2003)	Used the Offshore Safety Questionnaire (Rundmo, 1994; 1997; Mearns, Flin, Fleming & Gordon, 2001)	Yes	1. Determine associations between safety climate and accident involvement, and safety management practices and safety performance.
Silva, Lima, & Baptista (2004)	Self-developed, with some items from Ostrom, Wilhelmsen, and Kaplan (1993)	Yes	1. Develop and validate a scale assessing organisational climate and safety climate. 2. Examine relationship between survey and accidents.
Cooper & Phillips (2004)	Self-developed, with some items from Zohar (1980)	Yes	1. Validate the safety climate scale developed by Zohar (1980). 2. Determine relationship between safety climate and safety behaviour.
Seo, Torabi, Blair, & Ellis (2004)	Self-developed.	No	1. Develop and validate a safety climate scale.
Katz-Navon, Naveh, & Stern (2005)	Safety procedures scale adapted from Brunsson and Jacobsson (2000), safety information flow scale adapted from Hofmann and Stetzer (1998) and O'Reilly (1980), managerial safety practices scale adapted from Zohar (2000) and Hofmann and Stetzer, and priority of safety scale adapted from Zohar (2000).	Yes	1. Determine type and amount of relationship between separate dimensions of safety climate and treatment errors.

Zohar & Luria (2005)	Self-developed, with items derived from Zohar (2000).	Yes	1. Outline theoretical model of safety climate. 2. Test model by examining relationships between multiple levels of safety climate and safety behaviour.
Oliver, Tomas, & Cheyne (2006)	Scale jointly developed by universities at Loughborough (UK) and Valencia (Spain), refer to Cheyne and colleagues (1998)	Yes	1. Test the assumption that safety climate consists of shared perceptions. 2. Test whether safety climate is related to accidents in the workplace. 3. Test which individual dimensions are most predictive of accidents in a Spanish setting.
Neal & Griffin (2006)	Neal, Griffin, & Hart (2000)	Yes	1. Outlines theoretical model of safety climate. 2. Tests a multi-level model of safety climate over a 5 year period linking safety climate to motivation, safety behaviour, and accidents.
Hofmann & Mark (2006)	Uses items from a revised version of Zohar's (1980) scale by Mueller, DaSilva, Townsend, and Tetrick (1999) coupled with items from Rybowiak, Garst, Frese, and Batinic (1999)	Yes	1. Determine relationship between safety climate and back injuries, medication errors, urinary tract infections, patient satisfaction, patient perceptions of nurse responsiveness, and nurse satisfaction.
Wills, Watson, & Biggs (2006)	Used a modified version of Glendon and Litherland's (2001) Safety Climate Questionnaire.	No	1. To determine the relationship between separate dimensions of safety climate and work-related driving behaviours.

Johnson (2007)	Uses the group-level safety climate scale from Zohar and Luria (2005)	Yes	1. To test the psychometric properties of Zohar's (2000) safety climate measure. 2. To assess the predictive validity of safety climate.
Hahn & Murphy (2008)	Self-developed, uses a modified and shortened version of a scale developed by Dejoy, Searcy, Murphy, and Gershon (2000)	No	1. To develop and validate a short scale for assessing safety climate.
Baek, Bae, Ham, & Singh (2008)	Uses HSE (Health Safety Executive) survey	No	1. Examine level of safety climate and demographic factors (e.g. organisational size and tenure) that may affect safety climate scores in a Korean context.
Huang, Chen, DeArmond, Cigularov & Chen (2007)	Survey developed by a loss prevention unit in a worker's compensation insurance company, refer to Huang, Chen, Krauss, and Rogers (2004)	Yes	1. To determine the effect of safety climate and injury frequency on perceived injury risk, and how this relationship is affected by work-shift.
Matsubara, Hagihara, & Nobutomo (2008)	Self-developed.	Yes	1. To develop and validate a scale assessing safety climate in a Japanese context.
Neitzel, Seixas, Harris, & Camp (2008)	Self-developed, with some items from Griffin and Neal (2000).	Yes	1. To asses rates of noncompliance with fall hazard prevention requirements. 2. To assess safety climate, worker's knowledge and beliefs, and determine the relationship between safety climate and fall hazard injury risk.

Newman, Griffin, & Mason (2008)	Uses a modified version of Griffin and Neal's (2000) safety climate scale.	Yes	1. Outline model of safety climate in relation to safe work-related driving behaviour. 2. Test model by examining relationships between multiple levels of safety climate, safety motivation, driving self-efficacy, driving safety attitudes, and self-reported crashes.
Nielsen, Rasmussen, Glasscock, & Spangenberg (2008)	Uses the Danish Safety Culture Questionnaire, refer to Mikkelsen and Nielsen (in preparation).	Yes	1. Determine differences in safety climate and accident rates at two manufacturing plants.
Pousette, Larsson, & Torner (2008)	Uses a modified version of a scale developed by Cheyne, Cox, Oliver, and Tomas (1998)	Yes	1. Cross validate a previously attained factor structure and test whether a second-order safety climate factor exists. 2. Determine whether degree of agreement in workgroups differed between safety climate and safety attitudes. 3. Test predictive validity of safety climate.
Probst, Brubaker, Barsotti (2008)	Uses scale by Hecker, Gibbons, and Barsotti (2000)	Yes	1. Test the extent to which workplace injuries and illnesses are under-reported. 2. Test whether safety climate predicts the extent of under-reporting.

Strahan, Watson, Lennon (2008)	Uses the modified version of Glendon and Litherlands (2001) Safety Climate Questionnaire seen in Wills, Watson, and Biggs (2006)	No	1. Determine relationship between occupational stress and safety climate on fatigue-related driving behaviour and near misses.
Tharaldsen, Olsen, & Rundmo (2008)	Self-developed.	Yes	1. Develop and validate safety climate survey. 2. Determine changes in safety climate over time.
Turnberg & Daniell (2008)	Uses a modified version of Dejoy and colleagues (2000) safety climate scale.	No	1. Assess the psychometric properties of a modified safety climate scale.
Vinodkumar & Bhasi (2009)	Self-developed, with items derived from various other safety climate scales.	No	1. Develop and validate a safety climate scale for use in India.
Christian, Bradley, Wallace, & Burke (2009)	N/A	N/A	1. Meta-analytically examine the association between various situation/person-based variables and safety outcomes.
Beus, Payne, Bergmann, & Arthur (2010)	N/A	N/A	1. Meta-analytically examine the relationship between safety climate and injuries.
Lu & Tsai (2010)	Self-developed.	Yes	1. Examine the relationship between safety climate and safety behaviour.
Luria & Yagil (2010)	Self-developed semi-structured interview	Yes	1. Examine referents of safety perceptions among permanent and temporary employees.
Hansen, Williams, &	Patient Safety Climate in	Yes	1. Examine the association between safety climate

Singer (2010)	Healthcare Organizations (PSCHO) Survey (Singer, Meterko, Baker, Gaba, & Falwell, 2007)		perceptions and hospital readmission rates.
Lu & Yang (2011)	Self-developed.	No	1. Examine the effect of safety climate on self-reported safety behaviour in the passenger ferry context.

Hence, the studies by Vinodkumar and Bhasi (2009), who attempted to validate a scale in the Indian chemical industry context, or Turnberg and colleagues (2008), who attempted to validate a scale in the healthcare context, have valid and important goals. Zohar (2010) also stated that new scales should reflect recent advances in the safety climate literature, such as the separation of supervisor and management perceptions and the level-dependent aggregation of these scales. Though the safety climate literature has made remarkable progress in the past decade, these methodological aspects have been not as well acknowledged.

Out of the surveys included in Table 2, nearly one third did not aggregate their data, therefore not acknowledging the shared or emergent qualities of safety climate. Though the fact that most researchers aggregated their data is an improvement compared to the studies included in Guldenmund’s review, the lack of aggregation in a substantial portion of studies has a number of concerning conceptual and methodological implications. Firstly, the conceptual development of the construct may be hindered if there are fundamental differences in the way safety climate data is operationalized by researchers. In the organisational climate literature, it is generally agreed that climate perceptions analysed at the individual level refer to the construct of psychological climate, while aggregated perceptions refer to organisational climate. Though some authors in the organisational climate literature appear similarly ambivalent to conceptual developments and fail to label their choice of climate correctly (Kuenzi & Schminke, 2009), overall, differentiating psychological and organisational climate in this manner reduces conceptual ambiguity since researchers can distinguish between individual and group level theory. The aggregation of data also has important implications in terms of research findings. Kozlowski and Klein (2000) stated that relationships between constructs at the individual level may not hold at the group level. This was evident in a study by Ostroff and Rothausen (1997), where it was found that person-environment fit was affected by whether or not climate data was aggregated. Hence, studies which operationalise safety climate at the individual level may be contributing to further confusion in the literature given that their results may not be applicable to researchers who operationalise at the aggregate level. Additionally, given the shared nature of safety climate perceptions (Zohar, 2000; Oliver, Tomas, & Cheyne, 2006; Pousette et al., 2008), traditional single-level analyses are not appropriate given they assume independence of observations (Kreft & De Leeuw, 1998). By not acknowledging the dependency in perceptions, regression coefficients may be overestimated and standard errors underestimated (Twisk, 2006). Hence, studies at the individual level have potentially confounded results. Given these studies refer to "safety climate" rather than a distinct construct, it is evident the serious implications that arise from operationalizing safety climate at the theoretically and methodologically inappropriate level.

Aggregation due to the shared nature of climate perceptions is not a new concept, with Hoffman and Stetzer aggregating safety climate data in 1998, and Salancik and Pfeffer (1978) detailing its importance in the organisational climate field decades ago. Therefore, the ambivalence towards level-of-analysis is perplexing, particularly given the well-published ambiguity it promoted in the organisational climate literature. Kuenzi and Schminke (2009) suggested that the operationalization of organisational climate as an individual variable by some researchers may be due to pragmatic reasons, such as the inability to identify workgroups. Hence, similar reasons may be behind this occurrence in the safety climate literature. Kuenzi and Schminke suggested that if organisational climate is the construct of interest, then only aggregated data is appropriate, while if psychological climate is of interest, than only individual level data is appropriate. There needs to be a similar push to rename safety climate operationalized at the individual level, akin to what occurred in the organisational climate literature. Though safety climate operationalized at the individual level has been referred to as "perceived safety climate" (Neal & Griffin, 2006, p. 946) and "psychological safety climate" (Christian, Bradley, Wallace, & Burke, 2009, p. 1104), this is an uncommon occurrence. Given the previously mentioned ramifications of not operationalizing safety climate correctly, there appears to be a lack of awareness among researchers and journal editors on this issue.

Among those studies which did aggregate safety climate data, some methodological limitations are apparent. For example, some studies included items relating to perceptions of the supervisor/workgroup and management/organisation in the one scale (e.g. Hansen et al., 2010; Matsubara et al., 2008; Mearns et al., 2003; Neilsen et al., 2008; Pousette et al., 2008; Probst et al., 2008; Tharaldsen, et al., 2008) thereby reducing the specificity and usefulness of any feedback from the results. These studies do not appear to acknowledge the conceptual models of Zohar or Flin, which endorse the separation of organisational and group level targets of perceptions. Some of these studies also had individual level items (e.g. individual motivation) aggregated to the organisational level, which is fallacious given that the unit of theory (individual) is inconsistent with the unit of measurement (aggregate) (see Glick, 1985). A number of studies also aggregated their data without conducting the necessary tests to ensure sufficient homogeneity of perceptions (e.g. Mearns, Whitaker, & Flin, 2003; Neitzel, Seixas, Harris, & Camp, 2008, Johnson, 2007). Therefore, though there have been important conceptual developments in the past decade, these advances have yet to completely permeate research. Many authors incorrectly operationalize safety climate at the individual level, while others combine items relating to multiple levels of the organisation into a single scale.

2.7 Related Organisational Theories

The mechanisms in which safety climate affects an individual's behaviour and ultimately their likelihood of becoming injured can be explained or related to other organisational theories. Social exchange theory (Homans, 1958; Blau, 1964) is one such framework to explain these relationships. According to social exchange theory, when an individual acts in a way to benefit another party, an implicit unspecified obligation is created for this action to be reciprocated (Gouldner, 1960; Hoffman & Morgeson, 1999). A simple example of this is that if someone was to give a gift to another, there is an expectation that the person will reciprocate this act, though not necessarily by giving a gift in return (Blau, 1964). Social exchange theory has been related to more macro organisational behaviours, with the underlying premise being that if organisations act in a way which is supportive of their employees, employees will reciprocate this support through increased organisational citizenship behaviour (Konovosky & Pugh, 1994), increased performance and lower absenteeism (Tsui, Pearce, Porter, & Tripoli, 1997). Hoffman and Morgeson (1999) were the first to relate social exchange theory specifically to safety, stating that management commitment to safety in the form of training programs, participation in safety committees and other proactive behaviours may result in employees acting safer due to an implied obligation to reciprocate this commitment. Hoffman and Morgeson additionally found that safety commitment, safety communication, and accidents were related to this social exchange between management and frontline employees. It can be seen that social exchange theory and safety climate are similar concepts, with both theories involving some sort of implicit motivational driver being predicted by management behaviour. In social exchange theory, management safety actions instil an implied obligation that acts as a motivational driver, while in safety climate, management safety actions lead to the formation of behaviour-outcome expectancies that motivate/direct behaviour.

Elements of social exchange theory have also been integrated into leadership constructs such as leader-member exchange. Leader-member exchange refers to the "…quality and effectiveness of interpersonal relationships between leader and members" (Zohar & Luria, 2005, p. 626), and involve such factors as psychological distance, openness, and, as per social exchange theory, reciprocity (Graen & Uhl-Bien, 1995). It has been theorised that leader-member exchange is a proximal antecedent of climate (Kozlowski & Doherty, 1989), given that leader-member interactions are the primary medium to which the priority of safety is expressed. Research has found that higher quality leader-member interactions are associated with higher levels of safety climate (Hoffman, Morgeson & Gerras, 2003), with Zohar (2002) finding that this relationship was moderated by the safety priority of group-leader's supervisors. Zohar and Luria (2005) state that this demonstrates that employees discriminate between perceptions of leadership and perceptions of safety climate, indicating that social exchange theory and the related term of leader-member exchange are intertwined yet distinct from the construct of safety climate.

A number of other models can also be used to explain the relationship safety climate has with safety behaviour. One such model is expectancy-valence theory (Vroom, 1964), which describes how individuals engage in particular behaviours (and not other possible behaviours) due to an expectation of attaining some sort of desired outcome from that behaviour. The theory is very similar to operant conditioning; however operant conditioning's emphasis is on the environment shaping behaviour and not cognitive processes. In an organisational setting, if employees believe that acting safely will result in a desired outcome, they will therefore be more motivated to engage in safe behaviour (Neal & Griffin, 2006). Hence, the expectancy-valence theory is synonymous with the behaviour-outcome expectancies mentioned in Zohar's conceptualisation of safety climate.

Social learning theory (Bandura, 1969; 1977) similarly describes the motivational processes which may link safety climate with behaviour. Bandura's most important contribution to the literature was his work on observational learning, whereby individuals either change or learn new behaviours by observing an outside stimulus (Sims & Manz, 1982). In an organisational setting, supervisors and managers have been found to be important behavioural models (Sims & Manz, 1982). Employees not only imitate the behaviour of supervisors, if they observe a supervisor rewarding/punishing the behaviour of another employee, it will affect the frequency in which they perform that behaviour in the future (Sims & Manz, 1982). This parallels with the behaviour-outcome expectancies mentioned in Zohar's Multilevel Model of Safety Climate, as organisations in which safety has a high priority will be rewarding safe behaviour more often and supervisors will be acting in a safer manner, therefore modelling safe behaviour to employees. As Zohar states, employees perceive patterns in the practices and procedures of supervisors/managers, which infer the priority of safety and the likely consequences of behaviour, in other words through observational learning. Social learning theory is therefore another theoretically and empirically supported perspective to explain the process through which safety climate perceptions are linked to behaviour. In addition, similar findings to Zohar's research have been found in the social learning theory literature. For example, Weiss (1977; 1978) found that while employees tend to imitate the behaviour of supervisors, supervisors tend to imitate the behaviour of higher level managers. This was particularly the case if the supervisor was inexperienced and the manager was perceived as successful and competent. These results echo that of Zohar and Luria (2005), who found that the link between organisational safety climate and behaviour was mediated by group level safety climate, in other words, managers influence supervisors who in turn affect the behaviour of frontline employees.

Overall, there are a number of social/motivational theories that help explain and substantiate the process with which safety climate affects behaviour and ultimately injury. Social exchange theory, for example, proposes that management safety activities elicit feelings of obligation from employees to reciprocate this behaviour by acting safely (Hoffman & Morgeson, 1999). This motivational link between safety climate and behaviour is in line with the safety climate models of Neal and Griffin (2006) and Christian and colleagues (2009), where motivation is emphasised and separately measured when assessing the relationship between safety climate and behaviour. Elements of social exchange theory have more recently been integrated into the construct of leader-member exchange, which is regarded as an antecedent of safety climate (Kozlowski & Doherty, 1989). Expectancy-valence theory (Vroom, 1964) has also been related to safety climate (e.g. Neal & Griffin, 2006; Zohar, 2000), and is synonymous to the concept of behaviour-outcome expectancies motivating behaviour as expressed by Zohar (2000; Zohar & Luria, 2005). Finally, Bandura's (1969; 1977) social learning theory can also be used to explain how expectancies can direct employee behaviour. According to this theory, behaviours are learnt through observational learning. As per Zohar's theory, in organisations where safety has a high priority, safe behaviour will be rewarded more, increasing the frequency of safe behaviour occurring in the future among all those who observe these behaviour-outcome events. Therefore, though safety climate is a perceptual construct, when considered in relation to other psychological theories it is evident that perceptions inform behaviours through a combination of social, cognitive, and motivational processes.

2.8 Safety Climate Dimensionality

As stated previously, safety climate scales are rarely reused (Seo, Torabi, Blair, & Ellis, 2004), or their construct/predictive validity evaluated (Guldenmund, 2000), so unsurprisingly there is little consensus on the factor structure and dimensionality of safety climate. When studies have attempted to confirm a previously attained factor structure, the results have been inconsistent. It is commonly cited that when Brown and Holmes (1986) and Dedobbeleer and Beland (1991) reused Zohar's (1980) safety climate scale, they failed to produce the same factor structure. Additionally, in the few studies where authors have retested their measure in order to validate the factor structure (e.g. Cheyne et al., 1998; 2002; Cooper & Phillips, 2004; Coyle, Sleeman, & Adams, 1995; Glendon & Stanton, 2000; Thompson, Hilton, & Witt, 1998), it has been demonstrated that retesting on the same sample results in similar factor structures, whilst retesting on a different sample fails to replicate the factor structure. These earlier results suggested that safety climate factor structures were industry/sample specific. A review of recent studies does not challenge these previous results. Johnson (2007) appears to be the only researcher who has performed a confirmatory factor analysis on a previously developed scale in an unmodified form, where he validated the factor structure achieved by Zohar and Luria (2005) – however both studies were performed in the same industry (manufacturing).

Though the lack of scale reuse has meant there is not a generally accepted scale for any industry, this does not mean there is a complete lack of consensus on safety climate's dimensionality. Virtually all scales include the dimension of management commitment to safety (e.g. Brown & Holmes, 1986; Cooper & Phillips, 2004; Dedobbeleer & Beland, 1991; Mearns, Whitaker, & Flin, 2003; Zohar, 1980; Neal & Griffin, 2006; Zohar & Luria, 2005; Hahn & Murphy, 2008; Vinodkumar & Bhasi, 2009), with a meta-analysis by Beus, Payne, Bergmann, and Arthur (2010) finding that this dimension was the strongest predictor of future injuries. Supervisor commitment to safety is another common dimension (e.g. Mearns et al., 1998; Zohar, 2000; Zohar & Luria, 2005; Johnson, 2007). The frequency of these two dimensions reflect Zohar's (2000; 2003; Zohar and Luria, 2005) Multilevel Model of

Safety Climate. However, most authors do not adhere to Zohar's multilevel model and so the dimensions consist of a variety of other aspects of the working environment. Frequently reported dimensions include employee involvement (e.g. Cheyne, Cox, Oliver, & Tomas, 1998; Dedobbeleer & Beland, 1991; Mearns et al., 2003; Seo et al., 2004), the safety system (e.g. Cox & Cox, 1991; Mearns et al., 1998; Zohar, 1980) work pressure (e.g. Glendon & Litherland, 2001; Mearns et al., 2003; Zohar, 1980), communication (e.g. Cheyne et al., 1998; Glendon & Litherland, 2001; Mearns et al., 2003), competence (e.g. Carroll, 1998; Donald & Canter, 1994; Zohar, 1980) and perception of risk (e.g. Brown & Holmes, 1986; Mearns et al., 1998; Zohar, 1980).

Some of these dimensions, however popular they may be, may not represent safety climate at all (Beus et. al, 2010). As Beus and colleagues point out, the perception of risk is not a theoretically appropriate dimension given that risk may be independent of climate. For example, certain work environments such as offshore drilling or law enforcement may have a high perception of risk because of the nature of the work itself, not because of the organisation's commitment to safety. Beus and colleagues also identified personal safety attitudes and supervisor competence as commonly occurring dimensions which 'contaminated' the construct. This is because personal safety attitudes were not descriptive of organisations' policies, practices or procedures, a stance supported by Pousette and colleagues (2008), who found empirical evidence for a distinction between safety climate and attitudes. Supervisor competence is similarly not associated with their safety behaviours/commitment to safety. Beus and colleagues found that content contamination has a tendency to inflate the relationships between safety climate and injury, and suggested that researchers should develop their scales based on pre-existing theoretical frameworks. Such a recommendation is validated by a review of recently published studies which shows that some researchers who develop scales without ascribing to a particular pre-existing safety climate model include dimensions which do not represent the construct. For example, Baek and colleagues (2008) included items relating to job security and job satisfaction in their safety climate scale, factors which may be related to an organisation's commitment to safety, but are independent of it. Bjerken (2010) included risk as a dimension, which as previously stated, is more related to the nature of the work rather than an organisation's commitment to safety. Tharaldsen and colleagues (2008) included individual motivation as a safety climate dimension, which recent conceptualisations of climate (e.g. Flin, 2007; Griffin & Neal, 2000; Neal & Griffin, 2006; Christian et al., 2009) consider an outcome of safety climate rather than a component. Lastly, Vinodkumar and Bhasi (2009) included safety attitudes and the work environment in their scale, which are variables not consistent with contemporary conceptualisations of the construct.

Though the factor structure of safety climate has also been highly variable across studies, with the number of dimensions ranging from two (Dedobbeleer & Beland, 1991) to ten (Mohamed, 2002), Guldenmund (2000) believes this is unsurprising, given differences in question generation, labelling of constructs, and perhaps most importantly, sample characteristics influencing the dimensionality of the measure. Guldenmund points out that authors have sampled such disparate settings as industry (e.g. Brown & Holmes, 1986; Cox & Cox, 1991; Zohar, 1980), construction (e.g. Dedobbeleer & Beland, 1991; Mohamed, 2002), and health care (e.g. Coyle et al., 1995), and obviously differences will be apparent in what is pertinent for employees in each setting. Even Zohar (2010) regards having items specific to the industry as important, as it increases the sensitivity of the survey instrument for detecting within-unit and within-industry comparisons – however, Zohar believes these items should still relate to the policies/procedures of management/supervisors. Such a view is supported by the research of Seo and colleagues (2004). When Seo and colleagues validated a safety climate scale which included a number of the dimensions previously listed, they found that management and supervisor commitment to safety influenced other variables in their scale. The authors suggested that the lack of factor structure replication seen in the literature may be due to other researchers not taking into account these cross-loadings between manager/supervisor commitment to safety and other dimensions. What these results also suggest is that studies which assess other dimensions (e.g. safety systems, communication) are actually measuring second order constructs representing manager/supervisor commitment to safety. While the hierarchical structure of safety climate has rarely been tested, studies by Hoffman and Mark (2006) and Silva and colleagues (2004) have found support for a second order safety climate factor.

Though a number of safety climate dimensions have been proposed, both theory and research reflect management's central role in promoting a safe working environment. Supervisor commitment to safety is also a validated dimension, particularly in the manufacturing context (e.g. Zohar, 2000; Johnson, 2007). However, far fewer studies have separated perceptions of supervisors and examined their association with safety outcomes. Research by Seo and colleagues (2004) demonstrated the influence these two dimensions have on other dimensions commonly reported in the literature, supporting the notion that dimensions such as communication and safety systems are aspects of the underlying manager/supervisor commitment to safety. Though it is highly unlikely that a safety climate scale will be created which can be used in all work environments due to differences in sample characteristics, a number of researchers include dimensions in their scales which do not represent the construct (e.g. Baek et al., 2008; Bjerken, 2010; Tharaldsen et al., 2008; Vinodkumar & Bhasi, 2009). Content contamination can inflate associations with safety outcomes (Beus et. al 2010), make comparisons between study findings problematic, and potentially contribute to safety climate becoming as 'fuzzy' and all-encompassing as the organisational climate construct from which it was derived from.

2.8.1 Co-worker Safety Climate

A further level of the organisation which may impact upon employee behaviour and is a logical extension of Zohar's Multilevel Model of Safety climate is that of co-workers. A co-worker in this thesis will be defined as a fellow employee who works in the same area and who is situated at the same level of the organisational hierarchy. Co-workers may be particularly influential in organisations where supervisor and managers do not work very closely with frontline employees – leaving them self-directed for day to day tasks. This is increasingly common in contemporary organisations which have shifted from the traditional pyramid style hierarchical structure towards a flatter structure with empowered frontline employees (Clifford & Sohal, 1998). In self-directed work teams, team members are responsible for managing and planning their own work, setting team goals, and reviewing team performance (Irani, Sharp, & Kagioglou, 1997; Wellins, 1992). Hence, it is possible that co-workers may be an additional source of behaviour-outcome expectancies, with the effects of group norms or peer pressure on behaviour distinct from supervisory or managerial influences. Though authors such as Seo and colleagues (2005; 2004) and Lu and Tsai (2008) included aspects of co-worker commitment to safety in their safety climate scales (e.g. co-worker support and safety practices), the dimension of 'co-worker safety climate' has been largely ignored and its effects rarely studied separately in the safety climate literature. While Melia and colleagues (2008) examined co-worker safety climate at the individual level, only two articles to date have separately examined the role of co-workers in a multilevel safety climate scale. Heritage and colleagues (2012) demonstrated both the factorial validity and the cross-sectional criterion validity of a multilevel safety climate survey that included a co-worker safety climate scale. Brondino and colleagues (2012) found that co-worker safety climate mediated the relationship between supervisor safety climate and safety behaviour in their cross-sectional study. Hence, recent research supports the extension of Zohar's model to include co-worker safety climate, with further research required to validate the findings of these authors, particularly using a longitudinal design.

While there has been little research exploring the role of co-workers in the safety climate literature, there have been a number of studies in the general safety literature which has suggested that they hold an important role in promoting safe behaviour. For example, Burt and colleagues (1998; 2008) developed a scale measuring how caring co-workers were regarding safety, and though criterion validity of the scale was not tested, it was predicted that more caring co-workers would result in a better identification of hazards and communication of safety concerns among workers. Goldberg and colleagues (1991) found that co-worker support was associated with participation in safety programs, while Simard and

Marchand (1997) demonstrated that relations with co-workers was associated with safety compliance. Roy (2003) found that peer pressure among co-workers was a positive safety influence, for example in the wearing of safety equipment or other preventative behaviour, yet could also promote harmful norms such as a tolerance for risk. Finally, Zhou, Fang, and Wang (2008), using a technique known as Bayesian network modelling, found that manager commitment and workmate influences were the two most important predictors of safe behaviour. Hence, while co-worker commitment to safety is rarely included as a dimension on safety climate scales, it may have a significant influence on safety behaviour and therefore represents an important direction for safety climate research.

A secondary benefit of studying perceptions of co-workers is that it may provide a less biased insight into the safety behaviours of frontline employees in comparison to scales that ask the respondent to rate their own behaviour. Previous research has found that participants have a tendency to over-report behaviours deemed desirable by researchers or observers, and under-report behaviours that are deemed undesirable (Donaldson & Grant-Vallone, 2002; Moorman & Podsakoff, 1992). This is especially the case in organisational research, as employees may fear the prospect of employers gaining access to their responses, even if the possibility is extremely remote (Donaldson & Grant-Vallone). Therefore, the measurement of co-worker safety climate may be particularly valuable for the diagnosis of potential safety concerns in an organisation, as it may provide a more accurate and unguarded insight into the safety norms present among frontline employees than surveys that ask questions relating to an employee’s own behaviour.

2.9 Links to Safety Outcomes

To assess safety climate’s criterion or predictive validity, its association with a variety of relevant variables have been investigated. These variables include official injury/accident statistics, self-reported injuries/accidents, observed safety behaviour, and near misses, which refer to events where an injury/accident was close to occurring. Commonly, these variables are generically referred to as ‘safety outcomes’.

Cooper and Phillips (2004) argued that early research provided little compelling evidence of safety climate's ability to predict safety outcomes. In the construct's infancy, research was preoccupied with assessing psychometric properties such as factorial validity or discriminant validity; however there was little emphasis on the relationship safety climate had with safety outcomes (Cooper & Phillips, 2004). While some studies examined concurrent (cross-sectional) validity, Cooper and Phillips lamented the absence of studies examining the direct predictive validity of safety climate in their 2004 study. This lack of empirical evidence for safety climate's predictive validity led Cooper and Phillips to suggest safety climate only indirectly affected safety outcomes, however, contrary to their expectations, a direct relationship was demonstrated between safety climate and safety behaviour in their study. Though Cooper and Phillips were the first to demonstrate a direct link between these two variables, evidence began to accumulate for a direct relationship, with Naveh, Katz-Navon, and Stern (2005) and Johnson (2007) also finding that safety climate directly predicted safety behaviour.

Recent research has also provided evidence for safety climate predicting injury/accident outcomes. For example, Hoffman and Mark (2006) found that safety climate predicted the back injuries of nurses, while Johnson (2007) demonstrated direct associations between safety climate and injury severity. Johnson (2007) additionally found an indirect relationship between safety climate and injury frequency, mediated by safety behaviour. Furthermore, Silva, Lima and Baptista (2004) demonstrated that safety climate scores could discriminate between companies in terms of their injury rate and injury severity in a study involving 15 Portuguese companies. Therefore, while early research failed to support safety climate's direct predictive validity, recent research has provided mounting evidence for safety climate's ability to predict relevant safety outcomes such as safety behaviour and accident involvement.

There are a number of researchers who conceptualise safety climate as indirectly affecting safety outcomes, adhering to the models of Griffin and Neal (2000) and

Flin (2007). In this indirect approach, individual variables such as safety motivation or knowledge mediate the relationship between safety climate and safety outcomes. This approach has garnered considerable empirical support. In Neal and Griffin's (2006) 5 year study examining the lagged effects of safety climate, the authors found that safety climate predicted safety motivation, which in turn predicted self-reported safety behaviour. Self-reported safety behaviour was then found to predict organisational accident data. Newman, Griffin and Mason (2008) used Neal and Griffin's scale in addition to an adaptation of the scale assessing perceptions of supervisors to examine multilevel safety climate effects on driving behaviour. Their results echoed Neal and Griffin's study, with perceptions of management influencing safety motivation, which in turn was associated with self-reported crashes. In addition, there was an interaction effect, in which motivation to drive safely was higher among employees who perceived both their manager and supervisor valuing safety.

A meta-analysis by Christian and colleagues (2009) provided further evidence supporting the view that safety climate indirectly affects safety outcomes. Christian and colleagues found that while the association between safety climate and safety behaviour had a moderate effect size, the association between safety motivation/knowledge and safety behaviour had a large effect size. However, these results need to be considered in light of the studies which constituted the meta-analysis. As previously stated, the meta-analysis did not include cross-level effects, and very few studies utilised scales conforming to Zohar's Multilevel Model of Safety Climate.

Only a few studies have separated perceptions of supervisors and managers and examined cross-level effects, and very few studies have utilised Zohar's behaviour-based operationalization of the construct. As mentioned earlier, authors such as Zohar (2000; Zohar & Luria, 2005; 2010) and Johnson (2007) included items relating to specific behaviours and found direct effects. In contrast, authors such as Neal and Griffin generically assessed safety climate, with items referring to an overall commitment to safety. Hence, there may be methodological reasons behind the comparatively weaker association between safety climate and safety behaviour in Christian and colleague's meta-analysis. The finding in Beus and colleagues' (2010) meta-analysis that the safety climate→ injuries relationship constitutes a small effect further highlights the need for more studies to be conducted that use Zohar's behaviour-based operationalization of safety climate and which investigate cross-level effects. This will allow future meta-analyses to conduct comparisons between these different approaches to measurement. While Zohar acknowledges intervening variables such as behaviour-outcome expectancies/motivation, a question remains whether safety climate is a powerful enough predictor to reliably and directly predict safety outcomes, as suggested by Zohar's research. Determining this will have important implications for organisations, given they would have the confidence to perform interventions based solely on safety climate scale results.

Overall, there has been a shortage of longitudinal studies in the literature, particularly of the multi-level variety, with the majority of studies being cross-sectional in design. A cross-sectional design is a substantial limitation for any study examining the relationship between safety climate and safety outcomes, given it is difficult to establish whether safety climate scores are the product of previous injuries or whether injuries are the product of safety climate scores. Table 3 lists studies which have assessed the predictive validity of safety climate using a longitudinal design. Only studies which aggregated safety climate data have been included, given that individual level safety climate is not in line with theory and empirical research, and may demonstrate a different pattern of relationships with variables. From Table 3 it can be seen that most of the studies were conducted in the manufacturing or healthcare sector, with only one study conducted in the petroleum industry, however as previously stated that study incorrectly operationalized safety climate.

Many of the studies in Table 3 have a relatively small sample size, especially when the researchers were required to aggregate to the department/installation level. Though the difficulty in obtaining a sample is something all researchers can sympathise with, due to the infrequency of accidents/injuries, these studies may have had insufficient power to adequately gauge the relationships between safety climate and safety outcomes.

The majority of studies which are longitudinal tend to collect data for a short period of time, usually under a year and with two data points, with the exception of Neal and Griffin (2006), who collected data over a five year period. The meta-analysis by Beus and colleagues (2010) suggests that the overall brevity of longitudinal studies may not be a shortfall of the literature, with the authors finding that the predictive power of safety climate diminishes as the length of time injuries are assessed increases. These findings echo the sentiments of some authors who have defined safety climate in comparison to safety culture, with safety climate being a surface-level “snapshot” indicative of the underlying safety culture at a particular time (Cox & Cheyne, 2000; Glendon & Stanton, 2000).

Table 3

Longitudinal Studies Examining the Predictive Validity of Safety Climate

Author/s	Industry	Outcomes Variable/s	Length of Study (Data Points)	Sample Size (level of aggregation)
Hoffman & Mark (2006)	Healthcare	Injuries, Treatment Errors	3 months (2)	81 (workgroup)
Johnson (2007)	Manufacturing	Safe Behaviour, Injury Frequency, Injury Severity	5 months (2)	17 (workgroup)
Mearns, Whitaker & Flin (2001)	Petroleum	Self-reported accident involvement	12 months (2)	9 (installation)
Naveh, Katz-Navon & Stern (2005)	Healthcare	Treatment Errors	12 months (4: 2 data points in 2 hospitals)	21 & 15 (workgroup)

Neal & Griffin (2006)	Healthcare	Self-reported safety behaviour, self-reported safety motivation, accidents	60 months (5)	33 (workgroup)
Zohar (2000)	Manufacturing	Micro-accidents	5 months (2)	53 (workgroup)
Zohar & Luria (2005)	Manufacturing	Safe behaviour	3 months (2)	401 (workgroup) 36 (organisation)

To date, only Zohar and Luria (2005; 2010) have examined lagged relationships between multiple levels of safety climate and safety outcomes, where it was found that supervisor safety climate mediated the relationship between manager safety climate and safety outcomes. Hence, further research is necessary to explore lagged and cross-level relationships, given that Zohar and Luria's findings have not been replicated and because of the overall scarcity of longitudinal and multilevel safety climate studies. Given that meta-analyses have found that the association between safety and safety outcomes constitute a relatively small/moderate effect (Beus et al., 2010, Christian et al., 2009), further research is required to determine whether this is due to a distal relationship between these variables or because of the manner in which safety climate is operationalization by the majority of researchers. In addition, there are some industries, notably oil and gas, in which there has not yet been a theoretically and methodologically sound exploration of safety climate's predictive validity, as discussed in the next section. Therefore, though Zohar (2008) suggested that researchers should move beyond testing for associations with safety outcomes, with the absence of longitudinal and multilevel studies, such a recommendation was perhaps premature.

2.10 Safety Climate Research in the Oil and Gas Context

The current research project takes place in the oil and gas context, warranting further examination of safety climate research in this industry. The oil and gas context has long been the subject of safety research, not only because of the many dangers faced by employees working in this industry, but because of widely publicised safety failures such as the Piper Alpha oil rig disaster (Cullen, 1990). In this disaster, explosions and fires resulting from the ignition of leaking gas led to the oil rig collapsing and the loss of 167 lives (Cullen, 1990). As per the Chernobyl nuclear reactor disaster, a poor safety culture was deemed to be an important indirect determinant of the disaster (Cox & Flin, 1998). Inadequate training, poor communication systems, and the emphasis of production over safety were some of the organisational factors that led to the disaster taking place (Cullen, 1990).

Such disasters were a likely contributor to a surge of safety climate research in the oil and gas industry from the early 1990's, led by authors such as Rundmo (1992; 1994; 1995; Ostvik, Rundmo & Sjoberg, 1997; 2000; Tharaldsen, Olsen, & Rundmo, 2008) and Mearns (Mearns, et al., 1998; Mearns et al., 2001; Mearns et al., 2003). Early research by Rundmo (1992; 1994; 1995) assessed a variety of organisational factors in line with Zohar's (1980) early conceptualisation of safety climate, assessing dimensions such as communication, training adequacy, availability of protective equipment, and perceived risk. He found that these factors were associated with employee satisfaction, job stress, and experience of accidents and near misses. Ostvik and colleagues' 1997 study represented the first time a Rundmo authored research paper explicitly assessed safety climate, with the authors investigating the association between safety climate and emotional reactions in the offshore setting. Safety climate was conceptualised as consisting of values, beliefs, and attitudes, with their scale including items relating to satisfaction. Hence, while the conceptualisation of safety climate evolved from Rundmo's early studies, it is not in line with recent conceptualisations of the construct which consider values, beliefs, and attitudes to be the domain of safety culture (Guldenmund, 2000; Beus et al., 2010). In Rundmo's 2000 study safety climate was still considered an attitudinal construct, however common safety climate dimensions were assessed such as manager and supervisor commitment to safety. Rundmo found that the safety climate dimension "acceptability of rule violations" was the most important predictor of behaviour, however as per previous studies, the analyses were cross-sectional in design and safety climate was operationalized as an individual level variable. More recently, Rundmo was an author of a longitudinal study (Tharaldsen et al., 2008), which investigated the factor structure of a safety climate survey over a two year period. Associations with accidents were also investigated; however these were cross-sectional in design despite the two data points. While the study aggregated safety climate perceptions, reflecting developments in the literature since the earlier studies by Rundmo, their safety climate scale included the dimension of individual motivation. Individual motivation is not considered a dimension of safety climate but rather an outcome variable (Griffin & Neal, 2000; Neal & Griffin, 2006; Flin, 2007). Since individual motivation is theoretically an individual variable, by aggregating scores to the platform level the level of theory is inconsistent with the level of analysis (see Glick, 1985). Therefore, while Rundmo has contributed to the literature in terms of risk perception theory, his safety climate research has limited generalizability due to level-of-analysis issues and his choice of safety climate dimensions.

Research by Mearns et al. (1998; 2001; 2003) has similar limitations in terms of level-of-analysis and dimensionality. Mearns' early studies (Mearns, et al., 1998; Mearns et al., 2001) were all conducted on the individual level, and included a number of dimensions related to the overall organisational culture rather than the safety climate. For example, subscales assessed such disparate areas as risk perception, safety attitudes, and job security. Job security is distinct from an organisation's commitment to safety, while risk perception and attitudes are not considered safety climate dimensions in recent conceptualisations of the construct (Beus et al., 2010). Mearns aggregated safety climate data to the installation level in her 2003 study, and also made changes to the safety climate survey. However, safety climate was still operationalized as an attitudinal construct; particularly given there were items relating to satisfaction with safety activities (i.e. emotional/evaluative responses). The scale also included items relating to the frequency of unsafe behaviour, hence there were a mix of safety related attitudes and outcomes in the one scale. Mearns authored a study with Rundmo (Mearns et al., 2004) to investigate differences in safety climate between the Norwegian and UK context; however, the same criticisms can be levelled at the scale. Additionally, despite a number of offshore installations taking part in the survey, no aggregated associations with safety outcomes were investigated, with only descriptive differences between high and low accident installations explored. Recently, Mearns, Hope, Ford, and Tetrick (2010) examined the links between investment in health, safety climate, health climate, and safety behaviour in the offshore context. The authors found that investment in health was associated with safety climate, health climate, and individual commitment among employees. Data was aggregated and multilevel modelling techniques were used, therefore ensuring a more rigorous examination of the links between these variables compared to early studies. However, items relating to managers, supervisors, and the individual were included in the one scale, making it difficult to disentangle the distinct effects that these levels of the organisation have on safety outcomes.

Other studies which have investigated safety climate in an oil and gas context include those by Høivik, Tharaldsen, Baste, Moen (2009) and Bjerken (2010). These studies possess similar limitations to those described previously. Bjerken (2010) included risk perception as a safety climate dimension and did not aggregate safety climate scores when testing associations with safety outcomes. Høivik and colleagues used the same safety climate survey as Tharaldsen and colleagues (2008), which included individual motivation and management related items in the one scale. Additionally, the data was not aggregated and the focus was on descriptive differences between installations/organisations rather than the associations that safety climate has with relevant outcome variables. Høivik and colleagues acknowledged the severe shortage of studies investigating factors that affect health, safety, and the environment in the petroleum industry, and as evidenced by my review of relevant research, there is an even more critical shortage of studies in this area which are aligned with recent conceptualisations of safety climate. Very few studies have examined associations with safety outcomes, particularly using a longitudinal design, and fewer still have aggregated data to account for the dependency in climate perceptions. In addition, no safety climate studies in the oil and gas industry to date have separated perceptions of managers and supervisors and examined associations with safety outcomes. Therefore, substantial gaps of knowledge exist in the oil and gas safety climate literature given the lack of multilevel and longitudinal studies.

2.11 Summary

In the climate literature, there has been a history of ambiguity and confusion, with the leap to facet specific climates such as safety climate only partially avoiding these pitfalls. Developments such as Zohar's (2000; Zohar & Luria, 2005) Multilevel Model of Safety Climate and Flin's (2007) safety climate model provided a framework from which future research can proceed, however, few researchers have adhered to these conceptualisations of safety climate despite compelling theoretical, empirical, and methodological rationale. In Zohar's Multilevel Model of Safety Climate, researchers are encouraged to aggregate and separate perceptions of supervisors and managers. The strength of this approach compared to traditional approaches is that it acknowledges the shared nature of climate perceptions (Oliver, Tomas, & Cheyne, 2006; Pousette et al., 2008), the distinct influences of supervisors and managers (Simard & Marchand, 1997; Tomas, Melia, & Oliver, 1999; Zohar & Luria, 2005), and corrects for the lack of statistical independence in perceptions (see Kreft & De Leeuw, 1998). This approach also has practical benefits for organisations, given that the assessment of distinct behavioural domains at separate levels of the organisations provides specific and practicable feedback that interventions and improvements can be built around (Zohar, 2010). While Zohar has accumulated strong supporting evidence for his model (Johnson, 2007; Zohar, 2000; Zohar & Luria, 2005), some of his findings are yet to be replicated, and it is unknown whether his model generalises to the oil and gas industry. His model could also potentially be extended to include perceptions of co-workers, given research in related fields which suggest that co-workers are a powerful and distinct influence on behaviour (Roy, 2003; Simard & Marchand, 1997; Turner, Chmiel, Hershcovis, & Walls, 2010).

Another area of ambiguity in the safety climate literature is the operationalization of safety climate at the individual level. Not only are results potentially confounded since independence of observations are assumed, resulting in an underestimation of standard error (Twisk, 2006), there is the potential for the pattern of relationships at the individual level to be distinct from the pattern of relationships at the aggregate level (Kozlowski & Klein, 2000). It is unknown whether studies that operationalize safety climate at the individual level are generalizable to studies conducted at the aggregate level, since no comparisons have been performed between individual and aggregate operationalized safety climate.

Overall, despite the considerable progress made since Guldenmund's (2000) review over a decade ago, there are still some areas where the literature needs further development. This includes the replication and generalizability of Zohar's Multilevel Model of Safety Climate, the role of co-workers in promoting safety behaviour, the absence of multilevel and longitudinal research in the oil and gas industry, and the distinction between individual and aggregate level safety climate. Hence, the overarching goal of the current research project is to address these theoretically and practically relevant gaps in the literature.

Chapter 3

Aims, Rationale and Hypotheses

3.1 Overview

The overall aim of the thesis is to explore the relationships between safety climate perceptions at three levels of the organisation (manager, supervisor, co-worker), and the subsequent impact these separate levels of safety have on safety outcomes. By determining the nature and extent of these cross-level relationships, I aim to find support and extend upon Zohar's (2000; 2010; Zohar & Luria, 2005) Multilevel Model of Safety Climate. In addition, I aim to test whether Zohar's model generalises to industries other than the manufacturing context wherein it was tested. No multilevel safety climate scale has been tested in the oil and gas industry, so not only will Zohar's model and underlying theory be tested, but multilevel safety climate scales in the oil and gas industry generally. Additionally, I aim to determine whether co-workers are an additional source of behaviour-outcome expectancies, distinct from supervisor and managerial influences on behaviour. Despite research detailing the important role of co-workers in promoting safety within organisations, the dimension has been largely ignored in the safety climate literature and is not a component of Zohar's model. Hence, one of the objectives of this thesis is to test the relative importance of co-worker perceptions in predicting injury compared to other levels of the organisation. If co-workers are found to be an important predictor of safety outcomes, this has important ramifications for the dimensionality of safety climate surveys and the formulation organisational safety policy. Finally, I aim to examine the effect that level of analysis has on the relationship between safety climate perceptions and safety outcomes. Researchers have interchangeably operationalized safety climate at the individual and aggregate level, despite potential methodological confounds at the individual level and the possibility that level of analysis may significantly alter the pattern of relationships between safety climate and safety outcomes. Therefore, comparisons will be made between safety climate operationalized at the individual and aggregate level to further understand the effect that level of analysis and analytical technique has on these relationships. Such a comparison has not been done previously, and may have important ramifications on the interpretation of safety climate research in the past, present, and future.

In order to test these aforementioned aims, a number of specific hypotheses will be tested, separated into five objectives. Before the rationale behind each hypothesis is explained, the organisational context will be described.

3.2 Organisational Context

The research will take place in a large Australian-based oil and gas exploration and production organisation. The focus of the organisation is on liquefied natural gas (LNG) projects in the North-West Shelf off Western Australia; however the organisation has projects in other Australian states and internationally. These include oil and gas assets in Africa, Korea, Brazil, and the Gulf of Mexico, and over 3000 employees worldwide.

Recently, the organisation introduced a new competency framework aimed at improving the overall safety culture (Hayes, Novatsis, & Lardner, 2008). The framework was developed by adapting a previously developed framework, reviewing the safety literature, and through in-house research such as interviews and through the examination of incident review outcomes. This resulted in a framework covering four behavioural themes – standards, communication, risk management, and involvement. These themes were linked across three organisational groups – managers, supervisors, and everyone. By having the same behavioural themes across three levels of the organisation, it provided a common language for understanding safety culture, and allowed the framework to be integrated more easily into safety management and human resources systems. Hence, training and inductions referred to the competency framework, incident investigations looked at the presence/absence of behaviours listed in the framework, and communication in the form of meetings, posters, and magazines have all emphasised the framework's behavioural domains.

In order to track improvements in the safety culture over time in the organisation, an organisational safety climate survey was developed. As per the competency framework, the survey items reflected the four behaviour domains at three levels of the organisation. This survey developed by the organisation will be used to test the following objectives.

3.3 Objective One

Before the safety climate survey is used to assess lagged relationships with safety outcomes, its factorial validity will be assessed. Zohar (2010) emphasised the importance of developing industry-specific multilevel safety climate scales, and so the assessment of factorial validity is an important step in ensuring that valid results are attained from the survey. Given that some of the behavioural domains are similar to those used in Zohar's (2000; Zohar &Luria, 2005) safety climate scales, the assessment of factorial validity will provide further evidence that employees distinguish between these targets of their perceptions.

In order to assess each scale's factorial validity, confirmatory factor analyses will be performed, in which a correlated four-factor model will be compared against other plausible models using multiple fit indices. A correlated four-factor model should demonstrate superior fit indices compared to other models considering that safety climate is generally described as a multidimensional construct (Cooper & Phillips, 2004; Johnson, 2007; Zohar, 1980; Zohar & Luria, 2005), in which all dimensions measure distinct aspects of an underlying safety climate. In Zohar's Multilevel Model of Safety Climate, the underlying safety climate refers to manager or supervisor commitment to safety. Therefore, a correlated four-factor model, reflective of the four related yet distinct dimensions in each scale, should demonstrate a superior model fit compared to a one-factor safety climate model and a four-factor uncorrelated factors model.

Hypothesis 1: Confirmatory factor analysis of each scale will demonstrate that compared to a one-factor model or an uncorrelated four factor model, a correlated four-factor model (representing the four behavioural domains measuring distinct aspects of an underlying manager/supervisor/co-worker safety climate) best explains the relationships between variables.

3.4. Objective Two

The second objective will be to assess the cross-sectional criterion validity of each safety climate scale. A number of studies have demonstrated that safety climate is an important explanatory variable, with safety climate shown to be associated with a number of safety outcomes (Neal & Griffin, 2006; Johnson, 2007; Zohar, 2000). According to Zohar's Multilevel Model of Safety Climate, safety climate perceptions indicate the overall priority safety has at any given level of the organisation, leading to the development of behaviour-outcome expectancies. In other words, if an employee perceives that production speed is rewarded more than working safely, their behaviour will reflect this priority, increasing the likelihood of the employee becoming injured. Zohar and Luria (2005) state that employees develop complementary climate perceptions of multiple levels of the organisation, attending to the formal procedures of management and the subsequent implementation of these procedures by supervisors. Hence, it is expected that there will be significant associations between manager/supervisor safety climate and individual safety outcomes. While not included as a level in Zohar's Multilevel Model of Safety Climate, it is expected that perceptions of co-worker behaviours will also be associated with individual safety outcomes. This extension to Zohar's model is based on research demonstrating the important role of co-workers in promoting safe behaviour (e.g. Goldberg et al., 1991; Simard & Marchand, 1997), and therefore co-workers may represent a distinct source of behaviour-outcome expectancies.

Hypothesis 2: There will be significant negative associations between aggregated co-worker/supervisor/manager safety climate and individual safety outcomes.

3.5 Objective Three

Objective Three is for the predictive validity of the three scales to be assessed, in which safety climate scores in Year One will be associated with safety outcomes in

Year Two. Given the lack of longitudinal studies in the safety climate literature, particularly those which separate perceptions of managers, supervisors, and co-workers, this will provide some much needed insight into safety climate's lagged effects. In addition, no study to date has examined the predictive validity of a multilevel safety climate scale in the oil and gas industry, so not only will this be the first methodologically sound exploration of safety climate in the oil and gas industry, it will indicate whether Zohar's Multilevel Model of Safety Climate generalises to the oil and gas industry. As per the cross-sectional analyses, it is expected that employees in workgroups/facilities with lower safety climate will be more likely to experience an injury.

Hypothesis 3: There will be significant negative associations between aggregated co-worker/supervisor/manager safety climate in Year One and safety outcomes in Year Two.

3.6 Objective Four

For Objective Four, a series of five multilevel path models will be compared, as this will allow the replication and extension of the work of Zohar and Luria (2005), and provide insight into the lagged relationships among the nested levels of safety climate and injury given the absence of research on this topic. In each model, safety climate will be measured in Year One, while safety outcomes will be measured in Year Two. This reflects the work of Zohar and Luria (2005), who tested a mediation model consisting of manager safety climate, supervisor safety climate and safety behaviour in the same manner. By comparing a series of increasingly parsimonious nested models, a number of key insights will be made about the cross-level and lagged associations safety climate has with safety outcomes. The key questions that will be answered include:

1. Can Zohar's mediation model be replicated, and therefore does it generalise to the oil and gas industry?
2. Should Zohar's model be extended to include perceptions of co-workers?
3. If so, does co-worker safety climate mediate the relationship between supervisor safety climate and safety outcomes, similarly to how supervisor

safety climate mediates the relationship between manager safety climate and safety outcomes?

To answer these questions, the model seen in Figure 8 will first be compared with the model in Figure 9. This will provide an insight into whether individuals conduct unsafe behaviours (and get injured) because they develop behaviour-outcome expectancies based on observations of managers, supervisors, and their co-workers, or whether management commitment to safety filters down to supervisor and co-worker commitment to safety, and it is these more proximal group-level behavioural norms that an individual bases their own behaviour on. It is hypothesised that Model Two will demonstrate superior fit indices given the finding of Zohar and Luria (2005) that the relationship between manager safety climate and safety behaviour was mediated by the more proximal supervisor safety climate.

Hypothesis 4a: The model shown in Figure 9 will demonstrate superior fit indices compared to the model in Figure 8.

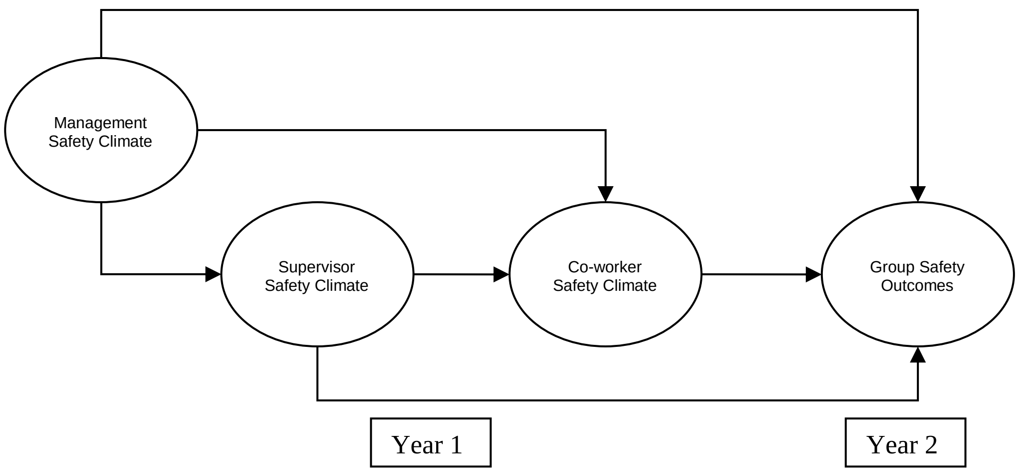

Figure 8. Model One: All paths included.

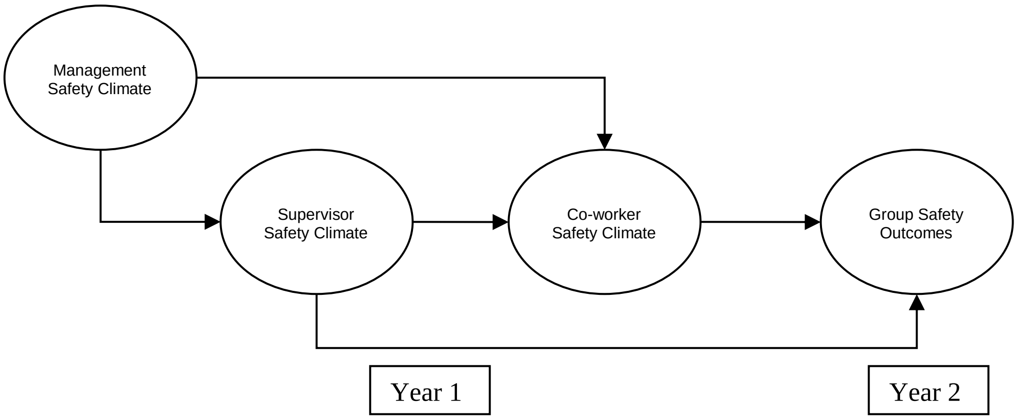

Figure 9. Model Two: Path between manager safety climate and safety outcomes removed.

Model Two will then have its fit indices compared to the model in Figure 10. This will determine whether manager safety climate directly affects co-worker safety climate, or whether co-worker safety climate is the sole product of supervisor safety climate. It is hypothesised that Model Three will demonstrate superior fit indices compared to Model Two given that frontline employees are rarely in contact with managers, and so it is more likely individuals would develop behaviour-outcome expectancies based on the actions of those around them (i.e. supervisors and co-workers).

Hypothesis 4b: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model in Figure 9.

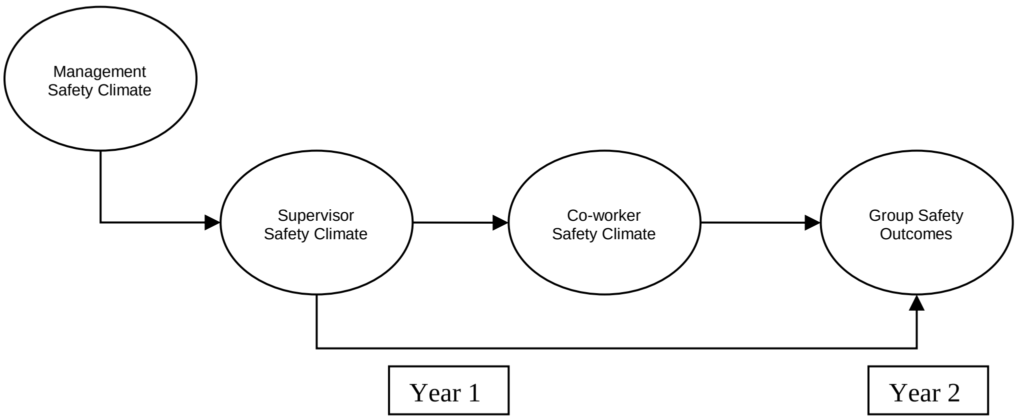

Figure 10. Model Three: Path between manager safety climate and co-worker safety climate removed.

The fit indices of the model in Figure 11 will be compared to Model Three. By comparing these two models it will be determined whether co-worker safety climate makes an important contribution to the prediction of employee safety outcomes as expected, or whether supervisor safety climate on its own adequately predicts employee safety outcomes.

Hypothesis 4c: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model seen in Figure 11.

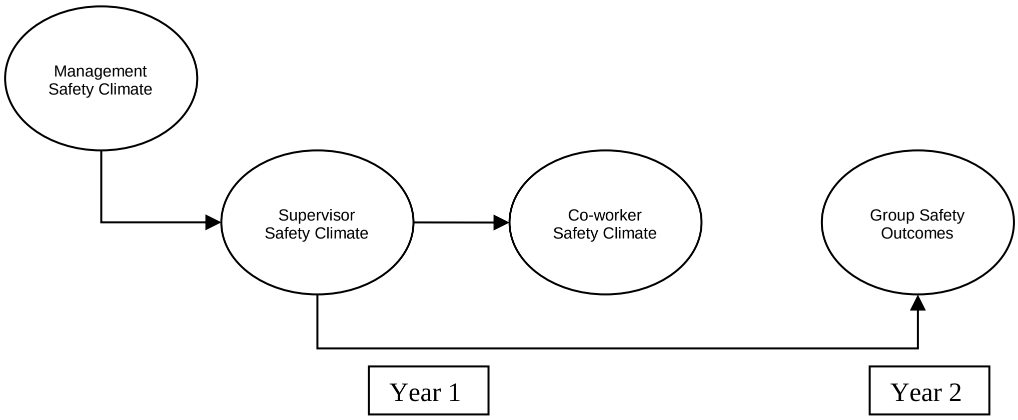

Figure 11. Model Four: Path between co-worker safety climate and safety outcomes removed.

Finally, Model Three will be compared to the model in Figure 12. In Model Five, the relationship between supervisor safety climate and employee safety outcomes is mediated by co-worker safety climate. Since it has been found that the relationship between manager commitment to safety and safety behaviour is fully mediated by supervisor commitment to safety, it is possible that the same relationship may apply with supervisor commitment and co-worker commitment to safety. This relationship makes a certain amount of intuitive sense given that a workgroup's norms would be influenced by supervisor commitment to safety, with workgroup norms perhaps being the predominant influence on an individual's behaviour. For example, research by Wagenaar and Groeneweg (1987) demonstrated that an individual's behaviour is most predicted by the norms of the workgroup rather than the formalised rules and procedures. However, given the large amount of research in the safety climate literature espousing the importance of supervisor commitment to safety (e.g. Mearns et al., 1998; Zohar, 2000; Zohar & Luria, 2005; Johnson, 2007), coupled with the fact that employees in the organisation are assumed to be in regular contact with supervisors and are thus likely to develop behaviour-outcome expectancies from them, Model Three is hypothesised to demonstrate superior fit indices compared to Model Five.

Hypothesis 4d: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model seen in Figure 12.

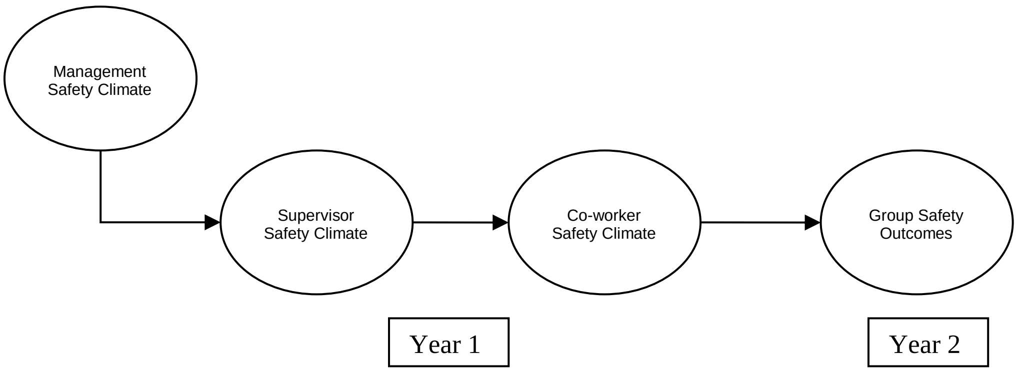

Figure 12. Model Five: Fully mediated model, with the path between supervisor safety climate and safety outcomes removed.

3.7 Objective Five

For Objective Five, comparisons will be made between safety climate operationalized at the aggregate and the individual level in order to determine the possible ramifications of inconsistent level-of-analysis in safety climate research. This will be investigated by comparing individual and aggregate operationalized safety climate in terms of their association with safety outcomes. These types of comparisons on a single dataset have not been undertaken previously in the safety climate literature and therefore there are no firm predictions on the likely results. For the comparison between aggregated multilevel and individual level safety climate, it is expected that the results will mirror the meta-analyses of Christian and colleagues (2009) and Beus and colleagues (2010), who found that individually operationalized safety climate demonstrated weaker associations with safety outcomes compared to aggregate safety climate.

Hypothesis 5a: Safety climate operationalized at the individual level will demonstrate weaker associations with safety outcomes compared to safety climate operationalized at the aggregate level.

While a small number of researchers distinguish between safety climate operationalized at the individual and aggregate levels (e.g. Christian et al., 2009; Neal & Griffin, 2006), the arbitrary labelling of the constructs by some researchers suggest this distinction is not entrenched. Safety climate operationalized at the individual level is potentially a distinct construct compared to aggregate level safety, and hence there is the possibility that it will exhibit a different pattern of relationships with safety outcomes. Such a finding would reflect other research which has demonstrated that level-of-analysis can affect the pattern of relationships between constructs (Ostroff & Rothausen, 1997; Kozlowski and Klein, 2000).

Hypothesis 5b: Safety climate operationalized at the individual level will demonstrate a distinct pattern of relationships with safety outcomes compared to safety climate operationalized at the aggregate level.

At the individual level, traditional versus multilevel analyses will be compared. For the multilevel analyses, corrections will be performed which control for group level variance, therefore acknowledging the lack of independence in climate perceptions. Though independence of observations is an assumption underlying standard analytical techniques (Kreft & De Leeuw, 1998), no study to date has operationalized safety climate at the individual level and controlled for group level variance. Hence, this comparison will indicate how the acknowledgement of dependency affects regression coefficients and standard error estimates, therefore determining whether the results of studies which have operationalized safety climate at the individual level (and not performed multilevel corrections) are potentially misleading. The results are expected to mirror the findings of Twisk (2006), who compared multilevel and non-multilevel analyses in the epidemiological context and found that multilevel analyses were much more conservative in their regression coefficients and standard error estimates.

Hypothesis 5c: Compared to standard analytical techniques, multilevel analyses will demonstrate smaller regression coefficients and larger standard errors.

A further test of the effects of level of analysis and analytical technique will be in path analysis model comparisons. Path analysis, typically using a structural equation modelling approach, is common in the safety climate literature, with a number of authors conducting these analyses at the individual level (e.g. Neal, Griffin, & Hart, 2000; Rundmo, 2000; Huang, Ho, Smith, & Chen, 2006). As per the previous objective, a number of path models will be compared to determine which model represents the best fit to the data. Unlike the previous objective, these analyses will take place at the individual level. The aim of this analysis is to determine whether the best fitting model at the individual level displays a different pattern of relationships compared to the best fitting model at the aggregate level. Given the large number of studies utilising path analysis at the individual level, this is an important avenue of research as it will further indicate whether safety climate assessed at the individual level is a distinct construct compared to safety climate at the aggregate level. This analysis is exploratory in nature, with no specific hypotheses about the manner in which the pattern of relationships will differ at the individual level compared to the aggregate level. However, it is expected that level-of-analysis will impact upon the observed pattern of relationships.

Hypothesis 5d: Compared to the best fitting aggregated multilevel path model, the best fitting individual level path model will display a different pattern of relationships between the safety climate scales and safety outcomes.

Overall, these analyses will provide a valid contribution to the safety climate literature. By testing the aforementioned hypotheses, an attempt will be made to replicate and extend upon Zohar's Multilevel Model of Safety Climate. Furthermore, the analyses will go some way towards addressing the lack of longitudinal and multilevel studies in the safety climate literature, particularly in the oil and gas context.

Chapter 4
Research Methodology

4.1 Research Design

Data collection consisted of two phases, separated by 12 months. Data from the first phase will be referred to as Year 1, and data from the second phase will be referred to as Year 2. In each phase, both safety climate and safety outcome data were collected from participants. The thesis will consist of both cross-sectional and longitudinal analyses. For Objectives 1 and 2, in which factorial and criterion validity are investigated, data will be from Year 1. For Objective 3, in which predictive validity is investigated, data will be from both Year 1 and Year 2. The safety climate data will be from Year 1 and the safety outcomes data will be from Year 2, so as to ascertain the lagged effects of safety climate on safety outcomes. For Objective 4, in which path models are compared, safety climate data will similarly be from Year 1 while safety outcomes data will be from Year 2. For Objective 5, in which comparisons are made between individual and aggregate levels of safety climate, data will be from Year 1. In order to perform longitudinal analyses, data will be individually linked from Year 1 to Year 2. Since the analyses involve the analysis of self-report questionnaires and injury frequency, the data gathered will be quantitative in nature.

4.2 Participants

All participants were frontline employees and permanent contractors working in one organisation in the oil and gas industry. Temporary contractors were not included in any analyses due to the possibility of them not having yet formed a cohesive perception of safety's priority, and because of research suggesting that temporary employees focus on different levels of the organisation in comparison to permanent employees (Luria & Yagil, 2010). Managers and supervisors completed the survey; however their data was not included in the analyses, since their understanding of the survey items may be very different to frontline employees. In comparison to frontline employees, supervisors and managers would likely have different working conditions, different exposure to risks, and they would likely have different targets of perceptions for items relating to co-workers/supervisors/managers. Hence, by only retaining the responses of front-line employees, a clearer and more relevant pattern of results was expected to emerge. The majority of employees participating were involved in the production of oil and gas; however a number of support staff, comprising such areas as engineering, maintenance, and HR, also completed the survey. Employees were provided with the survey as part of the organisation's ongoing safety culture improvement efforts, with the author provided access to the completed surveys in order to independently analyse the data. Participants were spread across a number of facilities, with the majority located in facilities in Australia, with some based internationally. No individually identifiable demographic information was collected in the survey to maximise participant anonymity, however organisational data states that approximately 75% of employees are male. In terms of age, organisational data states that 0.36% are <20, 17.8% are between 21-30, 33.78% are between 31-40, 29.42% are between 41-50, 16.38% are between 51-60, and 2.27% are >60. Participant numbers per year for each nested level of the organisation can be seen in Table 4. In Table 4, "Total Participants" refer to the number of frontline employees completing the survey, not including managers, supervisors, or temporary contractors. Workgroups referred to a group of employees, ranging in size from 4 to 60, who worked in a specific area together performing the same/similar duties. These workgroups were identified by the organisation. Eleven facilities took part in the survey in each year, however only nine facilities participated across both years.

Table 4

Respondents per Year for each Nested Level of the Organisation

	Total Participants	Workgroups	Facilities	Response Rate
Year 1	846	116	11	66%
Year 2	818	111	11	59%

<u>4.3 Measures</u>

4.3.1 Demographic Information

Participants indicated their place of work from a list of facilities, their length of employment (less than one year, one to five years, or more than five years), and their status as an employee or as a contractor. If the respondent indicated that they were a contractor, there was an additional question asking if they were a temporary or permanent contractor. Finally, the respondent was asked whether they were a manager, supervisor, or neither. In Table 5 the demographics of the initial sample in each year are displayed, hence it includes the managers, supervisors, and temporary contractors not included in any of the analyses.

Table 5

Demographic Information of Initial Sample in Year 1 and Year 2

	Year 1	Year 2
Organisational Role		
Manager	81	81
Supervisor	183	202
Neither	1005	985
Employment Status		
Permanent	780	862
Contractor	496	415
Temporary Contractor	204	194
Length of Employment		
Less than One Year	311	215
One to Five Years	657	580
More than Five Years	308	480

4.3.2 Safety Climate

While this thesis will be testing aspects of Zohar's Multilevel Model of Safety Climate, his scales are not being used. Instead, a survey developed specifically for the organisation was used. I was not involved in the development of this survey, but rather I was provided an opportunity by the organisation to use data from their survey in the thesis. However, as will be discussed, this survey has been through a thorough validation process and is theoretically consistent with Zohar's Multilevel Model of Safety Climate.

The organisation's safety climate survey is a self-report measure that assesses perceptions of commitment to safety at three levels of the organisation. The survey was developed in association with the introduction of a new competency framework aimed at improving the safety culture of the organisation. This competency framework came from a review of previous literature, in addition to the organisation's own in-house research. The framework focused on four behaviour themes (standards, communication, risk-management, involvement) at three levels of the organisation (manager, supervisor, everyone), which is reflected in the safety climate survey. Hence, there are three safety climate scales in the survey, with each scale assessing perceptions of a distinct level of the organisation, with four subscales in each scale, assessing the four behavioural themes.

In the survey, one scale assessed perceptions of manager commitment to safety, with the survey noting that managers are people above the respondent's direct supervisor. Therefore, the respondent's' perceptions were directed at management in their area/facility, not the top level management (i.e. CEO) of the organisation. Data for this scale therefore needed to be aggregated to the facility level. The supervisor scale asked respondents to rate the behaviours of their direct supervisor, indicating that it was the person the respondent typically reported to on a regular basis. This data needed to be aggregated to the workgroup level. The third scale assessed the commitment to safety of employees in the respondent's area or facility, in line with the 'everyone' aspect of the competency framework. While the level of aggregation necessary for the supervisor and manager scale was self-explanatory, for the area/facility scale it was somewhat more ambiguous. A number of items in the scale referred to fellow frontline employees, since they listed behaviours related to communicating with a supervisor. Though the instructions generically refer to a respondent's area/facility, fellow frontline co-workers appeared to be the subject of the items. The reference to a respondent's area/facility suggested aggregation to the facility level. However, given that the scale lists specific behaviours it is likely that an employee would relate the items to co-workers around them/in the same workgroup, rather than to employees in a completely different role in which they have little contact with. Analyses involving this scale will therefore be conducted at the group level throughout the thesis. In order to avoid level of aggregation being an alternative explanation for any findings, in Appendix B all analyses involving this scale will be conducted at the facility level. Additionally, the scale will be referred to more succinctly as the co-worker scale, given that fellow frontline employees appear to be the subject of the items.

In each of the three scales the respondent rated the perceived frequency of specific safety related behaviours on a six point Likert scale that ranged from 1 (*never*) to 6 (*always*). The co-worker and supervisor scales each had 18 items, while the manager scale had 22 items. Behaviours belonged to four distinct content themes for each of the three scales: standards, communication, risk management, and involvement. While the behavioural domains were the same across the three scales, the focus of the items differed between the scales to reflect the differences in responsibility throughout the organisational hierarchy.

4.3.2.1 Standards

The standards subscale overall assessed perceptions of the frequency in which compliance-type behaviours were performed by members of the organisation. In the co-worker scale, the standards subscale listed behaviours related to following rules for co-workers, for example, "identify impractical rules and procedures, and suggest improvements to their supervisor promptly". For the supervisor scale, the items referred to supervisors ensuring compliance among their subordinates, for example, "visits the worksite regularly to check compliance to standards, procedures and rules". For the manager scale, the items referred to management setting a high standard when it came to safety concerns, for example, "verify that the workforce understands and follows safety expectations". Given this dimension's focus on compliance-type behaviours, it is similar to the 'active' dimension in Zohar and Luria' s (2005) scale and the 'safety compliance' construct featured in Neal and Griffin's (2006) research.

4.3.2.2 Communication

The communication subscale overall assed perceptions of the frequency in which members of the organisation communicated openly and effectively in regards to safety concerns. For the co-worker scale, the communication subscale consisted of items related to speaking up, for example "report incidents, near-misses, unsafe conditions and sources of error promptly. For the supervisor scale, the subscale consisted of items related to encouraging the team, for example, "recognises and rewards good individual and team safety performance". For the manager scale, the subscale consisted of items relating to open communication with the workforce, for example, "communicate safety messages in a simple and direct manner". As per the standards subscale, the communication subscale has been featured in Zohar and Luria's scale, albeit under the name 'declarative practices'. Communication has also featured in a number of other safety climate scales (Cheyne et al., 1998; Glendon & Litherland, 2001; Mearns et al., 2003), hence it is a commonly used and well validated dimension.

4.3.2.3 Risk Management

The risk management subscale overall related to perceptions of the frequency of risk awareness and risk management behaviours were performed by members of the organisation. For the co-worker scale, the subscale included items relating to mindfulness and vigilance for safety among co-workers, for example, " take time to plan and organise the necessary steps and resources to do the job safely". For the supervisor scale, the items related to the promotion of risk awareness among subordinates, for example, "challenge assumptions and any complacency about routine work". For the manager scale, the items related to identifying and confronting areas of risk within the organisation, for example, "ensure hazards are identified and managed". The risk management subscale is the only subscale not to feature in Zohar and Luria's safety climate scales, however risk awareness and vigilance towards safety is a well-researched area in the safety literature (for a review, refer to Glendon et al., 2006). As will be discussed shortly, this dimension performed well in a previous validation study (Heritage, 2008), and conforms to Zohar's definition and operationalisation of safety climate due to its behaviour-based itemisation and its emphasis on enacted policies, procedures, and practices.

4.3.2.4 Involvement

The involvement subscale overall related to perceptions of the frequency of proactive or voluntary safety behaviours, in others, behaviours that go beyond simple compliance. For the co-worker scale, the subscale included items related to proactive involvement at the local level, for example "contribute to incident investigations". For the supervisor scale, items were related to the promotion of workgroup involvement in safety, for example, "initiates team discussions about safety performance:. For the manager scale, the items were related to the promotion of safety across the entire workforce, for example, "seek new ways to widen workforce involvement. As per the standards and communication subscales, the dimension of involvement is featured in Zohar and Luria's safety climate scale, though it was referred to as 'proactive practices'. The dimension is also known as 'safety participation' in Neal and Griffin's research (2006).

4.3.2.5 Psychometric Properties

Assessment of the safety climate survey's psychometric properties in its pilot year indicated that it had acceptable psychometric properties (Heritage, 2008). Confirmatory factor analysis performed on each scale demonstrated that a four factor correlated model, reflective of the four safety climate themes being assessed, exhibited superior fit indices compared to a one factor model and a four factor uncorrelated model. All scales demonstrated criterion validity by showing significant negative correlations with employee's self-reported near misses, with convergent validity additionally demonstrated as all scales exhibited significant positive correlations with scores on Zohar's (2000) validated safety climate scale. Internal consistency reliability, construct reliability and discriminatory capacity of items were also demonstrated to be acceptable for all scales. However, it must be noted that these findings were based on non-aggregated data obtained from solely self-report measures; hence there is a need for further evaluation of the scale's psychometric properties.

4.3.3 Injury Involvement

A format similar to that employed by Zacharatos, Barling, & Iverson (2005) and Oliver, Tomás, and Cheyne (2006) was utilised, in which respondents indicate through a self-report measure the frequency and severity of injuries they have experienced. Participants were asked to enter the number of times they had experienced a minor injury (requiring first aid), an injury (requiring medical treatment or more), and a near-miss (an incident which had the potential to cause an injury) in the past one year. This time period was chosen as it allows comparisons with annual self-reported injuries, providing an insight into trends over time as per the safety climate data. Since it was expected that minor injuries and injuries would be relatively rare events, for each participant the frequencies of minor injuries and injuries were summated to produce a "total injury" score. Self-reported near-misses were not summated with minor injuries and injuries since they were considered a distinct subjective perceptual construct. In comparison, minor injuries and injuries are less commonly occurring and are likely more clear-cut events of a more objective nature. Self-reported outcome variables are extremely common in the safety climate literature (e.g. Griffin & Neal, 2000; Hofmann & Stetzer, 1998; Mearns et al., 2001; Neal & Griffin, 2006; Seo et al., 2004), owing to the difficulty in attaining archival data from organisations, particularly workgroup specific injury data. While archival data is preferable to self-reported data, Christian and colleagues (2009) found no evidence of an inflationary bias when using self-reported data in comparison to archival data. Hence, it is expected that the self-reported data will be an accurate and valid indicator of an employee's actual experiences.

4.4 Procedure

Before any information was collected from participants, approval from Curtin's Human Research Ethics Committee was sought (approval number Psych 2008 06). To allow for data aggregation and multilevel analysis, all surveys were coded prior to distribution so that each respondent’s facility and work area could be identified. Questionnaires were provided to all production employees during the daily “toolbox meeting”, with employees not involved in production provided with the surveys during their ordinary working hours. Since all surveys were coded for a specific workgroup, packs of surveys were placed in a separate envelope for each workgroup and provided with specific instructions to ensure they were distributed to the intended workgroup. Collection of the data took approximately one month due to the geographical isolation of the production facilities coupled with the need to assess all employees on different shift rotations. All completed surveys were returned in individual envelopes to the company’s behavioural safety advisor by the organisation’s internal mail system. The behavioural safety advisor was the only person within the organisation who was in contact with the completed surveys, and when all surveys were collected from a facility, they were collected by the author.

Employees were asked to provide a unique code that will enable longitudinal data matching for individuals – this data will be used to determine the stability of workgroups. This item was listed as optional. The unique code was as follows:
First 3 letters of mother’s maiden name + day of date of birth
E.g. Johnson + 05/12/1980 = JOH05

4.5 Analytic Approach

In Objective One, the factorial validity of each scale will be assessed. Safety climate data from Year 1 will be used, with data left unaggregated to preserve power. Confirmatory factor analyses will then be performed using EQS 6.1, whereby the fit indices of a number of possible models will be compared.

For Objective Two, the cross-sectional criterion validity of each scale will be assessed. This will require safety climate and safety outcome data from Year 1. Safety climate data will be aggregated to the appropriate level (co-worker and supervisor scale = group, manager scale = facility) after demonstrating sufficient levels of intragroup/facility homogeneity of perceptions, and sufficient intergroup heterogeneity of perceptions. Homogeneity of perceptions will be tested by calculating intraclass correlation coefficients, while heterogeneity of perceptions will be tested via a series of one-way ANOVAs. Safety outcome data will remain at the individual level, so it can be determined whether an individual's membership of a group/facility is related to their possibility of becoming injured. Since safety climate data is at the aggregate level of analysis, and safety outcome data is at the individual level of analysis, multilevel data analysis techniques will be required. Multilevel logistic regression will be performed using MlwiN v.2.17 (Rasbash, Charlton, Browne, Healy, & Cameron, 2009), with a random intercept at the group level for co-worker/supervisor scale analyses, and a random intercept at the facility level for manager scale analyses.

For Objective Three, the predictive validity of each scale will be assessed. This will require safety climate data from Year 1 and safety outcome data from Year 2. As per the previous analysis, safety climate data will be aggregated and safety outcome data will remain at the individual level. In order to conduct this longitudinal analysis, the employee's unique code will be used to match data from Year One to Year Two.

For the path analysis comparisons in Objective Four, the fit indices of a number of multilevel structural equation models will be compared. Each safety climate scale will be aggregated to their respective level and safety outcome data will be aggregated to the group level. It was decided to aggregate safety outcome data since individual level data will require a three-level multilevel structural equation model, which is significantly more complex and requires more power in comparison to a two-level model.

For Objective Five, it will be examined whether there are differences in the pattern of relationships between safety climate operationalized at the individual level and at the aggregate level. This will be examined in two ways. Firstly, cross-sectional associations will be compared. It will be examined whether safety climate operationalized at the individual level, with no multi-level corrections, demonstrates a different pattern of relationships with individual level safety outcomes compared to safety climate operationalized at the aggregate level. It will also be seen whether performing multilevel corrections to individually operationalized safety will affect the size of regression coefficients and standard errors. Logistic regression techniques will be used to assess associations between safety climate and safety outcomes for both individual and aggregated analyses. Secondly, path models will be compared. It will be determined whether the best-fitting structural model when all scales are operationalized at the individual level is different to the best fitting model when all scales are aggregated to their respective levels.

4.6 Format of Subsequent Chapters

As previously stated, the hypotheses will be separated into five objectives, which will be assessed in the following five chapters. In Chapter Five, the factorial validity of each scale will be assessed, as per Objective One. Objective Two will be investigated in Chapter Six, where the criterion validity of each scale will be assessed. In Chapter Seven the predictive validity of each scale will be assessed, as per Objective Three. Path Models comparisons will be conducted in Chapter Eight, which will fulfil Objective Four. For Objective Five, comparisons will be made between individual and aggregate level safety climate, which will be contained in Chapter Nine. Finally, in Chapter Ten the implications of the findings will be discussed.

Chapter 5

Objective One: Factorial Validity of Safety Climate Survey

5.1. Introduction

Despite it being over 30 years since Zohar (1980) originally introduced the term 'safety climate', there still is a lack of consensus over its dimensionality. That is not to say that there has been no progress in determining the core dimensions of safety climate. Zohar's (1980) original scale included dimensions such as risk perception, effect of safe conduct on social status, work pace, and effects of safe conduct on promotion, all dimensions now obsolete and (predominately) not used in contemporary scales as the safety climate construct steadily becomes more succinctly defined. With the most widely agreed upon definition of safety climate referring to perceptions of an organisations commitment/priority to safety (Cooper & Phillips, 2004; Huang et al., 2007; Neitzel et al., 2008; Newman et al., 2008; Zohar, 2000), most recently developed scales do not include items relating to risk or attitudes, but rather visible aspects of the workplace which provide an indication of safety's priority.

While there is lack of consensus on which perceived aspects of the workplace are important and the theoretical model underlying these dimensions, there is near universal agreement that manager commitment to safety is a key dimension, and is featured in the majority of scales (Brown & Holmes, 1986; Cooper & Phillips, 2004; Dedobbeleer & Beland, 1991; Johnson, 2007; Mearns, Whitaker, & Flin, 2003; Zohar, 1980; Zohar & Luria, 2005; Hahn & Murphy, 2008; Vinodkumar & Bhasi, 2009). A number of studies also feature the dimension of supervisor commitment to safety (e.g. Mearns et al., 1998; Zohar, 2000; Zohar & Luria, 2005). The frequency of these dimensions reflect Zohar's Multilevel Model of safety climate, however since many researchers utilise a different theoretical model, other dimensions are commonly noted, such as employee involvement (e.g. Cheyne, Cox, Oliver, & Tomas, 1998; Dedobbeleer & Beland, 1991; Mearns et al., 2003; Seo et al., 2004), the safety system (e.g. Cox & Cox, 1991; Mearns et al., 1998; Zohar, 1980) work pressure (e.g. Glendon & Litherland, 2001; Mearns et al., 2003; Zohar, 1980), communication (e.g. Cheyne et al., 1998; Glendon & Litherland, 2001; Mearns et al., 2003), and competence (e.g. Carroll, 1998; Donald & Canter, 1994; Zohar, 1980).

There are a number of possible reasons for the lack of consensus over safety climate's dimensionality. The primary reason is the different theoretical models utilised by authors. According to Zohar's Multilevel Model of Safety Climate, employees develop safety climate perceptions from their interactions and observations of managers and supervisors, and so Zohar assesses various aspects of manager and supervisor behaviour. In Zohar's research, a dimension such as communication assesses an aspect of the underlying manager/supervisor commitment to safety, while in other studies the dimension of communication is considered as distinct to manager/supervisor commitment to safety. In other words, in some studies safety climate dimensions are theoretically loading onto a second-order 'general' safety climate factor, while in Zohar-based studies the second-order factor is explicitly identified as either manager or supervisor commitment to safety. However, an interesting and unintentional finding of Seo and colleagues, who used the 'general' safety climate factor approach, was that the manager and supervisor commitment to safety factor influenced other dimensions in their scale when they were testing their factor structure. These cross-loadings therefore supported Zohar's interpretation of the construct.

Adding to the complexity is that some studies operationalize safety climate as a unidimensional construct. For example, Neil and Griffin's (2006) safety climate scale had three items which assessed the general priority of safety demonstrated by management, with no specific behaviour or aspects of organisational management identified. Similarly, Newman, Griffin, and Mason (2008) assessed safety climate at the supervisor and management level, however the scales contained general statements regarding safety's priority rather than any multidimensional assessment of behaviour. Hence, differences in factor structure are unavoidable when there is such disparity in the operationalization of the construct due to differences in the researcher's theoretical orientation.

Secondly, it is expected that there will be different factor structures depending on the industry assessed (Guldenmund, 2000). Aspects of the organisation which are pertinent to employees in a manufacturing context are likely to be different to those in a healthcare context for example. Hence, some differences in dimensionality between scales are not necessarily a sign of safety climate being conceptually underdeveloped. Even Zohar (2010) states that having items specific to the industry is important, as it increases the sensitivity of the survey instrument for detecting within-unit and within-industry comparisons, however he believes that items should still refer to overarching manager or supervisor commitment to safety.

In the current objective, the factorial validity of a safety climate survey developed for the oil and gas industry will be assessed. Consistent with Zohar’s Multilevel Model of Safety Climate, there will be separate scales assessing perceptions of supervisor and manager commitment to safety, reflecting the key role these dimensions have in the safety literature. The survey extends upon Zohar’s model by including a scale measuring perceptions of co-worker commitment to safety, with the factorial validity of this scale also tested. Like Zohar’s scales, perceptions of distinct aspects of the organisational environment will be assessed in each of the three scales, with these dimensions relating to the underlying manager/supervisor/co-worker commitment to safety. The dimensions assessed in each scale are standards, communication, risk management, and involvement. The standards, communication, and involvement subscales are synonymous with the active, declarative, and proactive subscales in Zohar’s multilevel safety climate survey. The active and proactive subscales are in turn synonymous with the safety compliance and safety participation scales featured in Griffin and Neal’s (2000; Neal & Griffin, 2006) studies. The risk management subscale refers to individual vigilance towards safety, which is well researched area in the safety literature (Glendon et al., 2006). Hence all the dimensions are well supported by the literature, with the multilevel organisation of the survey theoretically and methodologically aligned with Zohar’s Multilevel Model of Safety Climate.

In order to assess each scale's factorial validity, confirmatory factor analyses will be performed, in which a correlated four-factor model will be compared against other plausible models using multiple fit indices. A correlated four-factor model should demonstrate superior fit indices compared to other models considering that safety climate is generally described as a multidimensional construct, in which all dimensions measure distinct aspects of an underlying safety climate (stemming from manager/supervisor/co-worker commitment to safety). Therefore, a correlated four-factor model, reflective of the four related yet distinct dimensions in each scale, should demonstrate a superior model fit compared to a one-factor safety climate model and a four-factor uncorrelated factors model.

Hypothesis 1: Confirmatory factor analysis of each scale will demonstrate that compared to a one-factor model or an uncorrelated four factor model, a correlated four-factor model (representing the four behavioural domains measuring distinct aspects of an underlying manager/supervisor/co-worker safety climate) best explains the relationships between variables.

While the safety climate subscales in each scale are considered to load on a second order factor representing co-worker/supervisor/manager commitment to safety, a hierarchical model will not be tested. In a previous validation study (Heritage, 2008), it was found that there was no appreciable difference in the fit indices between a hierarchical model and a non-hierarchical model, with the non-hierarchical model having marginally better fit indices due to its increased parsimony. Hence, due to its greater parsimony, only the non-hierarchical correlated four factor model will be tested.

5.2 Method

Data from Year 1 will be used. Please refer to Chapter Four for a full description of the participants, measures, and procedure.

5.3 Results

5.3.1 Year One Data Inspection

No item had over 5% data missing, with the highest frequency of missing data belonging to an item from the manager scale with 2.8% data missing. Overall, 5.5% of respondents had data missing in the co-worker scale, while 7% had data missing in the supervisor scale and 7.2% had data missing in the manager scale. Missing data analysis suggested that the data was not missing completely at random (MCAR) with Little's MCAR test reaching significance, $\chi2 = 5312.64$, $p < 0.05$. This was likely due to the higher frequency of missing data towards the end of the survey (i.e. the manager scale). Since no item had over 5% missing, it was not possible to test whether missing data was missing at random (MAR) through the separate-variances t-test. Therefore, due to the small amount of missing data, MAR was assumed.

If a participant did not answer over 50% of items in a scale, all the data for the scale was deleted, and was not used in the analyses. This resulted in two participants having their co-worker scale data removed, six participants having their supervisor scale data removed, and five participants having their manager scale data removed. If a participant missed more than one item in the standards, communication, risk management, or involvement subscale, data for entire subscale was deleted and not used in analyses. This resulted in two participants having their data removed for the communication and risk management subscales in the co-worker scale. For the supervisor scale, two participants had their communication subscale removed, three participants had their risk management data removed, and one participant had their involvement subscale removed. For the manager scale, four participants had their risk management data removed and two participants had their involvement scale removed. When a participant had only one item missing in a particular subscale, missing data was estimated via expectation maximisation. This technique was chosen since listwise or pairwise deletion would not be appropriate as the data was not MCAR. Overall, a total of 846 participants were retained for analysis.

5.3.2 Year One Descriptive Statistics

Table 6 presents the zero order correlations and Table 7 presents descriptive statistics for all scales and subscales. Since there was variability in the number of items per subscale, items means were used instead of the combined score for each subscale. The correlations between the subscales in a particular scale are indicative of their relative independence, and are also high enough to suggest that they are measuring the same underlying construct.

It can be seen that the mean scores for the safety climate scales/subscales are all between 4 (usually) and 5 (almost always); indicating that participants overall perceived managers, supervisors, and co-workers to frequently exhibit safety behaviours.

The internal consistency reliability of each subscale was assessed using SPSS 16.0. As seen in Table 8, the Cronbach's alpha each scale achieved by each subscale exceeded the 0.70 value recommended by Nunnally (1978). The lowest value achieved was by the standards subscale in the Co-worker scale, which is not surprising given it has the least number of items (N = 3) compared to all other subscales. Overall, the survey demonstrated acceptable internal consistency reliability across all scales and subscales.

Table 6

Zero Order Correlations between Variables

Variable	1	1a	1b	1c	1d	2	2a	2b	2c	2d	3	3a	3b	3c	3d	4	5
1. Co-worker Climate																	
1a. Standards	.84**																
1b. Communication	.89**	.70**															
1c. Risk Management	.88**	.68**	.71**														
1d. Involvement	.85**	.57**	.65**	.65**													
2. Supervisor Climate	.66**	.51**	.57**	.58**	.62**												
2a. Standards	.63**	.52**	.54**	.55**	.57**	.92**											
2b. Communication	.62**	.48**	.54**	.53**	.58**	.93**	.83**										
2c. Risk Management	.61**	.48**	.53**	.55**	.55**	.93**	.82**	.82**									
2d. Involvement	.58**	.43**	.48**	.50**	.58**	.93**	.78**	.81**	.84**								
3. Management SC	.66**	.51*	.57**	.58**	.60**	.66**	.63**	.62**	.59**	.61**							
3a. Standards	.63*	.50**	.57**	.54**	.57**	.63**	.61**	.59**	.58**	.58**	.93**						
3b. Communication	.62*	.49**	.54**	.51**	.54**	.58**	.55**	.55**	.52**	.54**	.95**	.86**					
3c. Risk Management	.61*	.52**	.57**	.54**	.57**	.63**	.59**	.59**	.57**	.58**	.95**	.85**	.87**				
3d. Involvement	.58*	.51**	.52**	.54**	.55**	.64**	.62**	.59**	.57**	.58**	.93**	.81**	.83**	.85**			
4. Near Miss	-.14*	-.11**	-.18**	-.11**	-.10**	-.07*	-.08*	-.10**	-.06	-.03	-.10**	-.13**	-.11**	-.09**	-.09**		
5. Minor Injury	-.05	.01	-.06	-.06	-.05	-.03	-.04	-.03	-.02	-.02	-.04	-.03	-.02	-.04	-.05	.16**	
6. Injury	-.03	-.02	-.02	-.03	-.03	-.05	-.03	-.07*	-.04	-.05	-.00	.01	-.01	.01	-.01	.096**	.22**

* $p < .05$ ** $p < .05$

Table 7

Descriptive Statistics for all Variables

Variable	Mean*	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
1. Co-worker Climate	4.63	0.65	1.29	6.00	-0.42	1.38
1a. Standards	4.66	0.71	1.00	6.00	-0.38	0.69
1b. Communication	4.83	0.69	1.17	6.00	-0.71	1.51
1c. Risk Management	4.67	0.72	1.00	6.00	-0.34	0.70
1d. Involvement	4.36	0.87	1.00	6.00	-0.43	0.40
2. Supervisor Climate	4.74	0.84	1.81	6.00	-0.69	0.42
2a. Standards	4.74	0.89	1.50	6.00	-0.66	0.16
2b. Communication	4.69	0.89	1.00	6.00	-0.59	0.32
2c. Risk Management	4.78	0.87	1.60	6.00	-0.71	0.44
2d. Involvement	4.74	0.96	1.00	6.00	-0.75	0.47
3. Management Climate	4.59	0.85	1.49	6.00	-0.60	0.41
3a. Standards	4.69	0.86	1.50	6.00	-0.60	0.32
3b. Communication	4.55	0.96	1.40	6.00	-0.61	0.17
3c. Risk Management	4.67	0.87	1.50	6.00	-0.72	0.64
3d. Involvement	4.45	0.95	1.00	6.00	-0.55	0.37
4. Near Miss	.43	1.60	0	20	7.06	61.86
5. Minor Injury	.47	1.19	0	12	4.27	25.41
6. Injury	.05	0.25	0	2	4.98	26.63

*minimum = 1 (never) maximum = 6 (always)

Table 8

Cronbach's Alpha Scores of each Subscale in the Safety Climate Survey

	Co-worker Scale	Supervisor Scale	Manager Scale
Standards	0.776	0.834	0.898
Communication	0.870	0.889	0.911
Risk Management	0.877	0.911	0.915
Involvement	0.873	0.919	0.927

5.3.3 Factorial Validity

5.3.3.1 Assumption Testing

The sample size of 846 greatly exceeds the minimum outlined by Kline (1998), who suggested having at least 10 participants per parameter. With the safety climate scales containing between 51 and 54 parameters, a sample size of 540 was required to reliably test the model.

Normality was a concern with the data, with all items achieving a significant Kolmogorov-Smirnov statistic when analysed using SPSS 16.0. However, due to this test's sensitivity in larger sample sizes, visual inspection of histograms and box plots were undertaken to determine if there were any practically significant deviations from normality. A negative skew was visible in the histograms and boxplots, with a number of univariate outliers likely contributing to the skew. Though the outliers were considered genuine extreme values, an attempt was made to remove them to determine if it would rectify the violation of normality. The removal of initial outliers did not correct the violation of normality, and so they were retained. Examination of Mardia's normalised estimate also indicated a violation of multivariate kurtosis. The 10 cases with the largest contribution to multivariate kurtosis were deleted from the dataset in an attempt to rectify the violation; though the resulting normalised estimate remained excessive and so these cases were retained. Since the maximum likelihood method (ML) of model estimation is based on the assumption of normality, and high multivariate kurtosis has the potential to distort the accuracy of fit indices (West, Finch, & Curran, 1995), robust fit statistics (Satorra & Bentler, 1994), which corrects for non-normality, were used in model estimation. Transformation of data for all items was not deemed necessary due to the use of robust fit statistics.

Linearity was assessed by examining randomly selected pairs of scatterplots, with all variables demonstrating linear relationships with one another. Multicollinearity and singularity was not deemed to be a problem as EQS was able to invert the matrices as part of the confirmatory factor analysis.

5.3.3.2 Factor Structure

Before the confirmatory factor analysis took place, an exploratory factor analysis with Varimax rotation was performed. For all three scales, a one factor solution was evident, with the scree plot clearly flattening out after one factor. Eigenvalues also suggested a one factor solution, with the supervisor and manager scales having only one factor with an eigenvalue greater than one, and the co-worker scale having one factor with an eigenvalue of 9.1, and the second potential factor having an eigenvalue of 1.4. This result was not surprising given the high correlations between subscales. However, as compared to exploratory factor analysis, confirmatory factor analysis is theory driven (rather than data driven) and does not capitalise as much on chance, and therefore the confirmatory factor analysis results are of greater relevance.

Model comparisons were conducted using EQS version 6.1 (Bentler, 2006). Comparison between an uncorrelated factor model, a one factor model, and a correlated four factor model for all scales can be seen in Table 9. For all scales, the four factor uncorrelated model achieved poor model fit, with no fit indices reaching their respective values indicative of a good fit. The one factor model achieved better model fit, achieving acceptable fit indices for the supervisor and manager scales. However, for all scales the correlated four factor model achieved superior fit indices. Though the correlated four factor model exceeded the recommended value of three for Satorra-Bentler chi-square divided by degrees of freedom (Kline, 1998), it surpassed the recommended value of .85 for the Comparative Fit Index and the Non-normed Fit Index (Bentler, 1990; Hu & Bentler, 1999) for all scales. The model also achieved a Root Mean Square Error of Approximation value well below the .08 threshold (Browne & Cudeck, 1993) for all scales, which further indicated that the model had a good fit to the data. Refer to Figure A1 in Appendix A where the measurement model is provided for the co-worker scale.

Table 9

Comparison of Models using Robust Fit Statistics

Model	S-B χ^2	df	S-B χ^2 /df	CFI	NNFI	RMSEA	AIC
Cut-off Criteria			< 3	= / >.85	= / >.85	= / <.08	*
Co-Worker Scale							
Four Factor Uncorrelated	2067.33	135	15.31	.65	.60	.13	1797.33
One Factor	1355.91	135	10.04	.77	.75	.10	1085.91
Four Factor Correlated	601.055	129	4.66	.91	.90	.07	343.06
Supervisor Scale							
Four Factor Uncorrelated	2743.77	135	20.32	.65	.60	.15	2473.77
One Factor	869.13	135	6.44	.90	.89	.08	599.13
Four Factor Correlated	605.07	129	4.69	.94	.92	.07	347.07
Manager Scale							
Four Factor Uncorrelated	3137.19	209	15.01	.69	.66	.13	2719.19

One Factor	1043.57	209	4.99	.91	.90	.07	625.57
Four Factor Correlated	725.24	203	3.57	.95	.94	.06	319.24

Note: S-Bχ^2 = Satorra-Bentler Chi-square statistic, S-Bχ^2 /df = Satorra-Bentler chi-square divided by degrees of freedom, CFI = Comparative Fit Index, NNFI = Non-normed Fit Index, RMSEA = Root Mean Square Error of Approximation, AIC = Akaike's Information Criterion, * = a lower AIC indicates a better fit.

A confirmatory factor analysis was additionally performed on Year 2 data to further demonstrate the stability of the factor structure over time (see Appendix A). The results mirrored that of Year 1, with a correlated four factor model demonstrating superior fit indices for each scale. Finally, a confirmatory factor analysis was performed to ensure that participants could differentiate between the three scales (see Appendix A). The results demonstrated that respondents clearly differentiated between the 3 scales, with a correlated three factor model (scales perceived as related yet distinct constructs) achieving far superior fit indices compared to a one-factor model (scales perceived as a singular homogenous construct).

5.4 Discussion

Overall, the survey performed well, demonstrating factorial validity through the superior fit indices of the four factor correlated model in comparison to the one-factor and uncorrelated four factor models. This provides evidence supporting Zohar's multilevel conceptualisation of safety climate, and provides evidence against a unidimensional operationalization of the construct. The superior fit indices of the correlated four factor model in comparison to an uncorrelated four factor model also demonstrates that even though employees differentiate between the behavioural themes, they still consider them to be measuring the same underlying construct (i.e. manager/supervisor/co-worker commitment to safety). The promising fit indices of the survey also provides some confidence to the organisation, as they can target interventions at particular behaviours knowing that employees are differentiating between the behavioural themes of each scale.

If the one factor model demonstrated the best fit indices in both the exploratory and confirmatory factor analysis, it would have suggested that safety climate was a unidimensional construct, with employees not differentiating between the behavioural themes of each scale. This would have supported the research of Neal and Griffin (2006) and Newman, Griffin and Mason (2008), whose scales portrayed safety climate as an unspecified, overall commitment to safety held by managers and/or supervisors. A one factor model having superior fit indices also would have suggested that the scales could be shortened, akin to the 3 item scale in Neal and Griffin, given that that each scale would have been perceived as analogous to each other.

However, since a correlated four factor model achieved superior fit indices, the findings support the majority of research which operationalizes safety climate as a multidimensional construct (e.g. Cooper & Phillips, 2004; Johnson, 2007; Mohammed, 2002; O'Toole, 2002; Zohar, 1980; Zohar & Luria, 2005). The benefit of this multidimensional structure is that it allows the organisation to target interventions at specific behavioural domains at specific levels of the organisation (provided the survey demonstrates predictive validity). This is a significant advantage over the shorter Neal and Griffin scale. Though a shorter scale has the benefit of being less laborious for both respondent and researcher, it does not provide the organisation sufficient insight into how to improve any safety climate deficiencies that may be found. Therefore, its practicality is limited in comparison to a multidimensional multilevel survey such as the one featured in the current analysis.

Overall, this analysis marks an important first step in the validation of a multilevel safety climate survey based on a clear theoretical model in the oil and gas industry. Unlike some studies which develop scales without a guiding theoretical model, in the current thesis Zohar’s Multilevel Model of Safety Climate provides a basis for the structure of the survey. However, before it can be established whether Zohar’s Multilevel Model of Safety Climate can generalise to the oil and gas industry and whether it needs to be extended to include perceptions of co-workers, the relationship between each scale and safety outcomes needs to be ascertained. Hence, the criterion validity of the survey will be assessed in the following chapter.

Chapter 6

Objective 2: Cross-sectional Criterion Validity

6.1 Introduction

A number of studies have examined the links between safety climate and safety outcomes. However, like the lack of consensus over safety climate's dimensionality, there exists substantial ambiguity in the literature on the type of relationship safety climate has with safety outcomes. Some researchers have found that safety climate has a direct relationship with safety outcomes. For example, Zohar (2000; Zohar & Luria, 2005) found that safety climate (at the supervisor level) predicted micro-accidents and safety behaviour. Johnson (2007), who utilised the same supervisor level scale, found that safety climate predicted safety behaviour and injury severity. In the healthcare, environment, Hoffman and Mark (2006) found that safety climate predicted medication errors and back injuries of nurses.

Some researchers argue that safety climate indirectly affects safety outcomes, with the relationship mediated by more proximal variables such as safety motivation and knowledge (e.g. Cheyne et al., 1998; Christian et al., 2009; Flin, 2007; Neal & Griffin, 2006; Neal, Griffin, & Hart, 2000). All of these models portray safety climate as affecting safety motivation/knowledge, which in turn predicts safe behaviour and the potential for injury. Though these models appear quite different to Zohar's Multilevel Model of Safety Climate, the mechanisms in which safety climate affects behaviour are very similar. Both Zohar's model and the previously mentioned mediation models include an intervening variable relating to an employee's propensity to work safely. While in the mediation models this is labelled as safety motivation/knowledge and measured separately, in Zohar's model the intervening variable is 'behaviour-outcome expectancies' and is not measured separately. As previously stated, both of these models have empirical support, with Zohar (2000) finding that his scale directly predicted micro-accidents, while Neal and Griffin (2006) found that the more proximal safety motivation predicted safety outcomes better than their measure of safety climate.

These inconsistent findings may be explained by the manner in which safety climate was operationalized. In Neal and Griffin's (2006) study, safety climate was measured by a 3 item scale that assessed perceptions of management's general safety priority. Hence, rather than examining perceptions of specific manager behaviours or organisational processes, it assessed perceptions of the general attitude management held towards safety. These perceptions were than associated with other self-reported variables such as motivation, which predicted safety participation and safety compliance, which in turn predicted accidents. Alternatively, in Zohar's scales the items were not a general assessment of manager commitment to safety, but referred to specific behaviours. Two of the subscales in Zohar's scale were synonymous with the variables of safety participation and safety compliance. Hence, the direct associations between safety climate and safety outcomes in Zohar's study may be the result of the behaviour-based operationalization of safety climate.

Adding to the ambiguity in the literature is the methodological deficiencies present in a number of studies examining the association between safety climate and safety outcomes. For example, many recent published studies still conduct analyses on the individual level (e.g. Seo, Torabi, Blair & Ellis, 2004; Wills, Watson, & Biggs, 2006; Hahn & Murphy, 2008; Strahan, Watson, & Lennon, 2008; Turnberg & Daniell, 2008; Vinodkumar & Bhasi, 2009) or combine items relating to supervisor and manager behaviour in the same scale, leading to fallacious inferences (e.g. Tharaldsen, Olsen, & Rundmo, 2008). Some studies which have performed aggregated analyses have not provided any indication that sufficient checks were made on the homogeneity of climate perceptions in the workgroup/organisation (e.g. Mearns, Whitaker, & Flin, 2003; Neitzel, Seixas, Harris, & Camp, 2008, Johnson, 2007), creating some uncertainty about the existence of shared climate perceptions in the organisation. Overall, there exists a shortage of studies in the literature which perform methodologically sound analyses, in which multilevel techniques are used to reflect the shared nature of climate perceptions. Therefore, while Zohar (2008) has stated that researchers should move beyond the development of new scales and scale validation, and explore new frontiers such as examining relationships between multiple climates in the workplace, such a recommendation may be premature given the continued ambiguity in the literature.

Further research is required to not only to replicate findings supporting a direct association between safety climate and safety outcomes, but also to determine whether the specification of further levels of organisational hierarchy will result in a more accurate prediction of injury. Though the separate assessment of supervisor and manager commitment to safety in Zohar's Multilevel Model of Safety Climate provides a more comprehensive picture of the organisational situation in comparison to a single scale, this does not necessarily prohibit further levels of the organisation from being separated and assessed. One such level is that of co-workers, which has been sporadically featured in safety climate scales (e.g. Seo et al., 2004; Lu & Tsai, 2008), but has only once been separated and aggregated as per the other levels in Zohar's model (see Brondino et al., 2012). This is despite an abundance of research demonstrating the importance of co-workers on safe behaviour in the workplace. For example, Roy (2003) found that peer pressure among co-workers was a positive safety influence, for example in the wearing of safety equipment or other preventative behaviour, yet could also promote harmful norms such as a tolerance for risk. Similarly, Simard and Marchand (1997) demonstrated that relations with co-workers was associated with safety compliance.

Hence, a co-worker safety climate could be posited to exist, with co-worker peer pressure and group norms being a source of behaviour-outcome expectancies distinct from supervisory and managerial influences. In Zohar's Multilevel Model of Safety climate, a supervisor safety climate exists because formal policies do not cover every single eventuality and so there is flexibility in interpretation and enforcement (Zohar & Luria, 2005). It is possible that a separate co-worker safety climate exists because supervisors are unlikely to control every action of frontline employees and so there is some flexibility in how tasks are seen to be completed by peers when the supervisor is not present. There will also be some differences between workgroups in terms of participation in safety discussions and investigations, the willingness of members to share their safety knowledge with those around them, the care directed towards other members in warning about potential safety concerns, and the likelihood of members identifying impractical procedures and suggesting improvements to their supervisor.

In this chapter, a preliminary assessment of the survey's association with safety outcomes will be assessed using data from the first year of data collection. Since the survey conforms to Zohar's Multilevel Model of Safety Climate, with multilevel methodology being used, the results of the analysis should help address the ambiguity evident in the safety climate literature. Furthermore, this will be the first time a study has separated and assessed the associations a co-worker level of safety climate has with safety outcomes. This will indicate whether Zohar's Multilevel Model of Safety Climate could be expanded to include co-worker perceptions, and whether co-workers deserve the relative lack of attention they receive in the safety climate literature.

Testing the criterion validity of the survey will also provide benefits to the organisation, given that the primary function of a safety climate survey is as a diagnostic tool. A validated, psychometrically sound scale allows an organisation to determine whether there is a safety climate deficiency in any facility, identifies behaviours in particular need of improvement, and provides the organisation with the confidence that changing organisational processes/personnel/training methods in response to these deficiencies will decrease the likelihood of injuries occurring. Therefore, it is hypothesised that each scale will demonstrate associations with safety outcomes, given previous research demonstrating the important role of managers, supervisors, and co-workers. Unlike studies such as Neal and Griffin (2006), which did not find a significant association between safety climate and safety outcomes, it is expected that the behaviour-based nature of the items in the current survey will result in a higher likelihood of significant effects. Since it is expected that a high commitment to safety will result in a lower frequency of injury, the direction of the relationship between safety climate and safety outcomes will be negative.

Hypothesis 2: There will be significant negative associations between aggregated co-worker/supervisor/manager safety climate and individual level safety outcomes.

6.2 Method

Data from Year 1 will be used. Please refer to Chapter Four for a full description of the participants, measures, and procedure.

6.3 Results

6.3.1 Criterion Validity

In order to perform multilevel analysis, safety climate data needed to be aggregated at the group level for the supervisor scales and at the facility level for the manager scale. The co-worker scale will additionally be aggregated to the group level. While the scale asks respondents to rate the perceived frequency of behaviours of everyone in their area/facility, some of the items specifically refer to fellow frontline employees. Given that the scale lists specific behaviours it is likely that an employee will be relating the items to co-workers around them/in the same workgroup, rather than to employees in a completely different role in the facility. In order to avoid having level-of-analysis as an alternative explanation for any findings, the cross-sectional criterion validity analyses will additionally be performed using facility-level perceptions of co-workers (see Appendix B).

To justify aggregating data to the group and facility level, a number of analyses were undertaken to determine whether there was sufficient within group homogeneity and between group heterogeneity in responses. A commonly used method to determine the dependency of climate perceptions within a group is the intraclass correlation coefficient (ICC). The ICC can be defined as the variance between groups (whether that be workgroups or organisations) divided by the total variance, hence the ICC informs us of the proportion of variance accounted for by group membership (Twisk, 2006). The ICC can vary between 0 and 1, with an ICC of 0 indicating that all variance is accounted for within an individual, while an ICC of 1 indicates that all variance is due to group membership. In the majority of cross-sectional studies, ICC's will not be above 0.20 (Twisk, 2006). There is no clear-cut minimum ICC that indicates that multilevel analyses are required, however some researchers suggest interpreting ICC's as a measure of effect size (Bliese, 2000; LeBreton & Sentor, 2008). Based on the traditional effect size thresholds of Cohen (1988), an ICC of 0.01 indicates a small effect size, a value of 0.10 indicates a medium effect size, and values in excess of 0.25 indicate a large effect size (LeBreton & Sentor, 2008). LaBreton and Sentor suggest numbers as low as 0.05 can indicate an important group effect.

Before the calculation of group level ICC's were conducted, all respondents from groups containing less than three people were deleted (N = 34), given that groups with one or two members may artificially inflate the average homogeneity of responses within groups. Next, surveys where the workgroup code was not legible were also removed from the analysis. This process resulted in the deletion of 57 cases. Overall, a total of 95 workgroups were included in the analyses. To calculate the ICC for each scale, an intercept only model was created in SPSS v16.0, where the workgroup code/facility was the grouping variable and the mean safety climate score (co-worker scale/supervisor scale/manager scale) was the dependent variable. Though safety climate is a multi-dimensional construct, treating it as a unidimensional construct for the calculation of ICC's was considered justified, as correlations between subscales were extremely high and it provided an overall indication of the homogeneity of perceptions per level of the organisation. In the intercept only model there are no predictors (though safety climate will be a predictor in subsequent analyses), it simply informs us of the proportion of variance in safety climate within groups and between groups. The ICC's for each scale were as follows: 0.125 (12.5%) for the co-worker scale, 0.136 (13.6%) for the supervisor scale and 0.088 (8.8%) for the manager scale. These numbers are somewhat lower than what some authors have achieved, with Zohar and Luria (2005) attaining ICC's of 0.22 and 0.17 for the manager and supervisor scales respectively. However, the scores are definitely not abnormally low, with Neal and Griffin achieving scores of 0.051 and 0.02. These scores indicated that there were sufficient homogeneity of responses within groups and thus multilevel techniques were required to account for the dependency in responses. The ICC for the co-worker scale was 0.101 (10.1%) when aggregated to the facility level (in the determination of whether the group or facility level was the more appropriate level of aggregation). This indicated some homogeneity in perceptions; however since the ICC was lower at the facility level as compared to the workgroup level, the workgroup level was deemed to be the more appropriate level of analysis for the co-worker scale.

According to Oliver, Tomas, and Cheyne (2006), in addition to determining the level of within group homogeneity via ICC's, to further justify aggregation a test of between group variance should be undertaken. Hence, a one-way analysis of variance using unaggregated data was tested. A respondent's workgroup was the independent variable when testing the co-worker and supervisor scales, while facility was the independent variable when testing the manager scale. The dependent variable was the mean safety climate score. Results indicated that all safety climate scales exhibited significant between group variance, Co-worker Scale: F (95, 751) = 2.03, $p < .001$ ($\eta_p^2 = .227$), Supervisor Scale: F (95, 738) = 2.18, $p < .001$ ($\eta_p^2 = .244$), Manager Scale: F (10, 736) = 7.83, $p < .001$ ($\eta_p^2 = .097$). These results coupled with the ICC's suggest a need to consider the safety climate perceptions as "shared" at the group/facility level, and therefore requiring aggregation and multilevel analysis.

To assess the criterion validity of the survey, a number of multilevel logistic analyses were performed using MLwiN v2.17 (Rasbash et al., 2009). The logit link function was utilised, with a random intercept added to the model. No significant amount of overdispersion was present in the data; hence parameter estimates were calculated under the assumption of a standard binomial distribution. Models were first computed using 1st order marginal quasi-likelihood (MQL) approximation, from where it was determined whether a random slope was required. Second-order predictive quasi-likelihood (PQL) approximation was then used, with this process resulting in less biased estimates and less chance of convergence problems (Rashbash et. al., 2009). Standardised residuals and influence diagnostics were inspected to determine the presence of any extreme values. For the majority of subscales there were no outliers detected, however for some subscales between 1 and 3 outliers were removed. Models were then recomputed using 2nd order PQL approximation. The results of the analyses can be seen in Table 10, with significance values calculated via the Wald test.

The results indicate that the co-worker scale is not a good predictor of safety outcomes. Though the parameter estimates with self-reported near misses were in the correct direction, the estimates for total scale score and for all of the subscales failed to reach significance for either self-reported near misses or injuries. For injuries, the associations with co-worker safety climate were in the opposite direction to that expected, with error scores similar or larger than parameter estimates, indicating a negligible or conflicting association.

Supervisor safety climate scale results were more positive. Parameter estimates were in the correct direction for the scale and its subscales for both near misses and injuries, with the total scale and three out of four subscales shown to be significantly negatively associated with near misses. Similarly to the co-worker scale, neither the total scale nor its subscales demonstrated significant associations with self-reported injuries.

The manager safety climate scale additionally did not demonstrate significant associations with self-reported injuries; however it did show a significant association with self-reported near misses. The Involvement and Communication subscales were also seen to be significantly negatively associated with self-reported near misses, with the Standards and Risk Management subscales falling marginally short of the 0.05 threshold. Hence, partial support for Hypothesis 2 was found, with the supervisor and manager scales demonstrating significant associations with self-reported near misses.

Logistic regression analyses allow the calculation of odds ratios, which indicates the relative risk of a particular outcome occurring given the presence of a particular factor. It is derived by calculating the exponential function of the regression coefficient. For the supervisor scale, the odds ratio is 0.46. This indicates that a group with a mean supervisor scale score of 5 has 0.46 times the likelihood of experiencing a near miss compared to a group with a mean supervisor scale score of 4. The 95% confidence interval is a relatively large, ranging from 0.24 to 0.86, due to the small range of scores. For the manager scale, the odds ratio is 0.26, with a 95% confidence interval ranging from 0.07 to 0.92.

Table 10

Multilevel Logistic Regression Analyses between Injury Involvement and Safety Climate

	Near Miss		Injury	
	Estimate (SE)	p Value	Estimate (SE)	p Value
Co-worker Scale	-0.613 (0.445)	0.169	0.315 (0.328)	0.336
Standards	-0.464 (0.389)	0.233	0.273 (0.295)	0.354
Communication	-0.681 (0.424)	0.108	0.155 (0.316)	0.623
Risk Management	-0.701 (0.409)	0.087	0.440 (0.299)	0.141
Involvement	-0.524 (0.345)	0.129	0.181 (0.275)	0.510
Supervisor Scale	-0.785 (0.324)	0.015*	-0.280 (0.239)	0.242
Standards	-0.652 (0.291)	0.025*	-0.163 (0.216)	0.449
Communication	-0.988 (0.314)	0.002*	-0.343 (0.232)	0.139
Risk Management	-0.755 (0.328)	0.021*	-0.204 (0.240)	0.395
Involvement	-0.535 (0.302)	0.076	-0.312 (0.227)	0.170
Manager Scale	-1.342 (0.645)	0.037*	-0.138 (0.506)	0.784
Standards	-1.267 (0.720)	0.078	0.004 (0.525)	1.000
Communication	-1.100 (0.500)	0.028*	-0.211 (0.414)	0.610
Risk Management	-1.373 (0.795)	0.084	0.185 (0.553)	0.738
Involvement	-1.272 (0.560)	0.023*	-0.286 (0.456)	0.530

* $p < 0.05$

The relationship between the co-worker scale and safety outcomes was also assessed with the co-worker scale aggregated to the facility level (See Table A3 in Appendix B). Other than the level of aggregation, analyses were conducted in the same manner as before, with one outlier detected and removed from the analysis. As per the group level analyses, the co-worker scale did not demonstrate a significant association with either self-reported near misses or injuries. Three out of four subscales also did not achieve significant associations with self-reported safety outcomes, with the exception of the involvement subscale. This subscale achieved a marginally significant negative association with self-reported injuries. All subscales additionally demonstrated associations with self-reported injuries in the opposite direction to that expected.

6.4 Discussion

Zohar (2000; Zohar & Luria, 2005) theorised that safety climate affected employee's behaviour-outcome expectancies, which in turn influenced future behaviour. While managers and supervisors were viewed as the source of these expectancies in Zohar's model, I proposed that co-workers were another distinct source in the current analysis. Therefore, while Zohar and Luria's (2005) Multilevel Safety Climate Scale had two levels, measuring manager and supervisor commitment to safety, this analysis attempted to include a third level measuring co-worker commitment to safety. Though the co-worker safety climate scale demonstrated sufficient internal consistency reliability and factorial validity, the most important feature of a safety climate scale is its ability to predict workplace injuries, given that it is used to diagnose potential safety concerns in the organisation, thereby promoting the use of focused interventions. Unlike the scales assessing the supervisor and manager levels of the organisation, the co-worker safety climate scale did not demonstrate any significant associations with self-reported near misses or injuries. This was the case regardless of whether the scale was aggregated to the group or facility level.

Given evidence from authors such as Roy (2003), who found that co-workers can promote harmful norms such as a learned tolerance for risk, and by Simard and Marchand (1997) and Goldberg and colleagues (1991), who found that co-workers can influence safety compliance and safety participation, the current results are surprising. A likely explanation is that co-workers are not an important source of behaviour-outcome expectancies. This either indicates that employees, in this company at least, are relatively autonomous and do not coerce other employees to act in a particular way and/or that supervisors are a much more influential source of behaviour-outcome expectancies. Given that supervisors are responsible for punishing/rewarding safe/unsafe behaviour, the prospect of losing one's job or future promotion possibilities is evidently more palpable than trying to fit in with fellow employees. Overall, in a high risk company such as the one currently studied, where it is inferred that there is a high degree of supervision, perceptions of co-worker commitment to safety appears to not be as important in determining behaviour.

The results of the analysis provide strong support for Zohar's Multilevel Model of Safety Climate. According to Zohar's model, employees develop behaviour-outcome expectancies based on the perceived priority of safety compared to production concerns. These behaviour-outcome expectancies stem from management (organisational level climate) and supervisors (group level climate), since the policies espoused by management do not cover every eventuality, thus leading to a degree of supervisory discretion in the manner policies are implemented. Though the scale used in the current analysis is different to that used by Zohar in his research, the criterion validity of the Supervisor and Manager Safety Climate Scales lend support to his previously discussed model of safety climate. This is an important finding, given that this is the first multilevel safety climate scale to be validated after Zohar and Luria's (2005) effort. Since Zohar's research has taken place in the manufacturing sector in Israel, and the current analysis takes place in the oil and gas industry in Australia, the findings demonstrate that Zohar's model can be generalised to other industries and it can be used to develop a scale that is specific to the needs of a particular organisation. Given the large differences in the current objective's sample and Zohar's sample, the findings indicate that Zohar's model may be applicable to other industries.

The results also support a largely untested aspect of Zohar's model. As stated previously, individual employees develop behaviour-outcome expectancies based on the perceived priority of safety, with Zohar and Luria (2005, p. 617) stating that

"…individual employees, as members of the organization as a whole and of subunits in that organization, develop consensual multilevel assessments of the most significant environmental features in terms of desired role behavior, and then they act accordingly". Since an individual's behaviour reflects their perceived priority of safety, in environments where safety has a low priority, individuals should therefore be more likely to conduct unsafe behaviours and experience injury. Only Zohar (2000) has tested the relationship between group level climate and individual injury, with no study to date examining the relationship between organisational level outcomes and individual injury. While no significant association was evident between safety climate and injuries, the current findings, in which both supervisor and manager commitment to safety demonstrated associations with individual self-reported near misses, are supportive of Zohar's stance that shared safety climate perceptions affects individual level safety outcomes.

The significant associations between the supervisor/manager scales and safety outcomes also tentatively suggest a direct relationship between safety climate and safety outcomes. Though the cross-sectional design of this analysis prohibits causal statements from being made, the strong associations between safety climate and safety outcomes is more in line with Zohar's (2000) findings than Neal and Griffin (2006), in which a significant association was not found. The findings therefore suggest the superiority of a behaviour-based itemisation of safety climate in comparison to the shorter, more generalised commitment to safety measure featured in Neal and Griffin (2006), and Newman, Griffin, and Mason (2008).

Overall, the criterion validity of the scales coupled with their ability to pinpoint interventions at particular behaviours at particular levels of the organisation strongly suggest that behaviour-based safety climate scales would be of greater practical value to an organisation. While the results are promising, a longitudinal design would allow more definitive statements to be made on the relationship between the safety climate scales and safety outcomes. In the next chapter, the predictive validity of each scale will be assessed, in which a longitudinal design will be employed.

Chapter 7

Objective 3: Predictive Validity of Safety Climate

7.1 Introduction

While a number of studies have examined safety climate's lagged effects since Zohar (2000) first found evidence of a predictive relationship between safety climate and safety outcomes, few have followed Zohar's lead by separating perceptions of managers and supervisors. This is despite Zohar's rationale for separating perceptions of managers and supervisors having strong theoretical and methodological support. According to Zohar's Multilevel Model of Safety Climate (Zohar, 2000; Zohar & Luria, 2005) employees have coexisting perceptions of commitment to safety at multiple levels of the organisational hierarchy, with these perceptions producing behaviour-outcome expectancies, in other words, they provide an indication of the consequences for safe or unsafe behaviour. These perceptions are directed towards the enacted policies of management and of the implementation of policies by supervisors, reflecting a number of studies which have consistently identified manager and supervisor commitment to safety as key dimensions of safety climate (e.g. Brown & Holmes, 1986; Cooper & Phillips, 2004; Dedobbeleer & Beland, 1991; Johnson, 2007; Mearns, Whitaker, & Flin, 2003; Zohar, 1980; Zohar & Luria, 2005).

Separating perceptions of managers and supervisors also has a number of methodological advantages. Firstly, it permits the use of analytical techniques that reflect the shared nature of safety climate within workgroups/organisations (Oliver, Tomas, & Cheyne, 2006; Pousette, Larsson, & Torner, 2008). Within an organisation, there are a number of co-existing climates (Zohar & Luria, 2005), for example, each workgroup may develop shared climate perceptions of their supervisor, while organisation-wide climates may exist based on overall shared perceptions of management. Zohar therefore aggregated data to the workgroup level (supervisor safety climate) or organisational level (manager safety climate) to take into account these shared perceptions at different levels of the organisational hierarchy. This has significant advantages over studies which conduct their analyses on the individual level (e.g. Seo, Torabi, Blair & Ellis, 2004; Wills, Watson, & Biggs, 2006; Hahn & Murphy, 2008; Strahan, Watson, & Lennon, 2008), since aggregating data and conducting multilevel analyses takes into account the dependency of observations.

A secondary advantage of separating and aggregating safety climate perceptions is that it avoids conceptual ambiguity, since safety climate assessed at the individual level versus the aggregate level are essentially separate constructs, and are labelled as such by some authors (e.g. Neal & Griffin, 2006). Relationships which hold at the individual level do not necessarily hold at the aggregate level (Kozlowski & Klein, 2000), and so by having safety climate aggregated to a level consistent with theory the conceptual development of the construct is promoted.

Despite some strong supporting evidence for Zohar's methodology and theoretical model (e.g. Zohar & Luria, 2005; Oliver, Tomas, Cheyne, 2006; Johnson, 2007), the number of studies which have separated the perceptions of supervisors and managers and examined lagged effects have been rare. Though a number of longitudinal studies have found that safety climate directly predicts safety outcomes (e.g. Cooper & Phillips, 2004; Johnson, 2007; Naveh, Katz-Navon, & Stern, 2005) and others have demonstrated a mediated effect (e.g. Clarke, 2010; Newman, Griffin, & Mason, 2008; Neal & Griffin, 2006), to the author's knowledge, only two studies have examined the leading effects of safety climate with separate scales assessing perceptions of supervisor and manager commitment to safety. Both of those studies were conducted by Zohar and Luria (2005, 2010), who found significant associations between workgroup level (supervisor) safety climate and safety behaviour, and between organisational level (manager) safety climate and safety engineering audit scores in both studies. The authors additionally observed that the association between organisational level safety climate and safety behaviour was mediated by workgroup level safety climate, with transformational supervisors protecting employees from a harmful organisational level safety climate.

A small number of longitudinal studies have also separated perceptions of safety climate, yet looked at specifically supervisor or manager commitment to safety.

Zohar (2000) was the first to demonstrate a predictive relationship between safety climate and safety outcomes, with group level (supervisor) safety climate predicting micro-accidents in the manufacturing industry. Johnson (2007) found similar results in his validation of Zohar's group level scale, conducted similarly in the manufacturing industry, with perceptions of supervisor commitment to safety predicting safety behaviour and injury severity. Neal and Griffin (2006) alternatively concentrated on management commitment to safety, and found that it was associated with subsequent individual safety motivation in the hospital environment.

Few studies to date have separately examined the lagged effects of other possible levels of the organisation hierarchy, for example co-workers. Though supervisors and managers are highly influential due to their ability to reward or punish behaviour, a number of studies have demonstrated the importance of co-workers in promoting safe behaviour (e.g. Roy, 2003; Simard & Marchand, 1997; Zhou, Fang, & Wang, 2008). While co-worker commitment to safety is a largely unstudied aspect of safety climate, it may have a significant separate influence on safety behaviour in comparison to supervisor and managers and therefore represents a potentially important direction for safety climate research.

Overall, there is a shortage of studies which have examined the lagged effects of safety climate, and which have also separated perceptions and accounted for the dependency of observations at different levels of the organisational hierarchy. The current objective aims to address these shortcomings in the literature by examining the lagged effects of safety climate via a multilevel safety climate survey that is in line with Zohar's theoretical model. In addition to testing the predictive validity of separate scales assessing perceptions of manager and supervisor commitment to safety over a period of one year, a scale examining perceptions of co-worker commitment to safety will also be assessed. As per the cross-sectional analyses, it is expected that all scales will demonstrate significant lagged associations with safety outcomes.

Hypothesis 3: There will be significant negative associations between aggregated co-worker/supervisor/manager safety climate in Year One and safety outcomes in Year Two.

Overall, no study to date has examined the predictive validity of a multilevel safety climate scale in the oil and gas context. This provides an opportunity to determine whether Zohar's theoretical model is applicable to the oil and gas industry, given that it has only been tested in the manufacturing context. Secondly, this analysis will indicate whether perceptions of co-workers deserve a more prominent place in the safety climate literature, given their potential to be a key leading indicator of safety outcomes.

7.2 Method

In order to assess lagged associations between safety climate and safety outcomes, safety climate data from Year 1 and safety outcome data from Year 2 will be used. Refer to Chapter Four for a full description of the participants, measures, and procedures. In addition to self-reported outcome data as described in Chapter 4, official organisational injury data was available in Year 2. The organisational records did not include near miss data, nor did it include injury data at the workgroup level. Since the Year 2 data represents a separate phase of data collection, the data will first be inspected and descriptive statistics calculated.

7.3 Results

7.3.1 Year Two Data Inspection

No item had over 5% data missing, with the highest frequency of missing data recorded on a single item being 4.8%. Overall, 4.6% of participants had data missing in the co-worker scale, 6.3% had data missing in the supervisor scale, and 6.1% had data missing in the manager scale. As per the previous year, the data was not missing completely at random (MCAR), with Little's MCAR test reaching significance, $\chi^2 = 5312.47$, $p < 0.05$. Since no item has over 5% missing, it was not possible to test whether missing data was missing at random (MAR) through the separate-variances t-test. Therefore, due to the small amount of missing data, MAR was assumed.

If a participant did not answer over 50% of items in a scale, the data for the entire scale was deleted. This resulted in six participants having their supervisor scale data removed, and 20 participants having their manager scale data removed. If a participant missed more than one item in a particular subscale, data for that entire subscale was deleted. When a participant had only one item missing in a particular subscale, missing data was estimated via expectation maximisation. Overall, a total of 818 participants were retained for analysis.

7.3.2 Year Two Descriptive Statistics

Table 11 presents the zero order correlations and Table 12 presents descriptive statistics for all scales. Since there was variability in the number of items per subscale, items means were used instead of the combined score for each subscale. The correlations between the subscales in a particular scale are indicative of their relative independence, and are also high enough to suggest that they are measuring the same underlying construct.

It can be seen that the mean scores for the safety climate scales/subscales are closer to their maximum than their minimum; indicating that participants overall considered the organisation to have a good commitment to safety. However, scores were on the whole lower than Year 1. Another difference compared to Year 1 was the strength of the correlations between safety climate and safety outcomes. While virtually all scales and subscales demonstrated a significant negative correlation with self-reported near misses in Year 1, in Year 2 no scale or subscale managed to achieve this, pointing to an overall weakening of the association between safety climate and safety outcomes within the organisation.

7.3.3 Preliminary Analyses

In order to determine the leading effects of safety climate on safety outcomes, it was initially planned to utilise the personal code present on each survey to link individuals' data from Year 1 to Year 2. This individual data would then have been able to be aggregated to the workgroup/facility level to allow longitudinal multilevel analyses to take place. However, the number of respondents with personal codes which could be matched to the same workgroup was extremely low, with only 36 participants having useable data. Since these 36 participants still needed their data aggregated for the multilevel analyses, the resulting analyses would be too underpowered and the dataset would likely be unrepresentative of the population. The lack of personal code data was due to the majority of individuals not completing this optional item in the survey. It is difficult to ascertain why respondents did not provide a personal code. Since the item clearly stated that it was optional and for external research purposes, it is possible that respondents did not feel as compelled to provide the code. It is also possible that respondents were fearful that the code would lead to their identification. A minority of respondents went as far as to obscure or remove the workgroup code found on the front of the survey, likely due to this fear of identification, and so there is some evidence for this interpretation.

Since individual data linking was not possible, it was necessary to use aggregated data from both years sampled, whereby aggregated safety climate scores in Year 1 would be tested for association with aggregated safety outcomes in Year 2. Though this approach does not have the statistical rigour of multilevel analysis, it is far superior to using individual level data since it acknowledges the lack of independence among individual respondents.

Table 11

Zero Order Correlations between Variables (Year 2)

Variable	1	1a	1b	1c	1d	2	2a	2b	2c	2d	3	3a	3b	3c	3d	4	5
1. Co-worker Climate																	
1a. Standards	.85*																
1b. Communication	.91*	.73*															
1c. Risk Management	.91*	.72*	.81*														
1d. Involvement	.86*	.57*	.68*	.69*													
2. Supervisor Climate	.68*	.57*	.62*	.59*	.61*												
2a. Standards	.65*	.55*	.59*	.55*	.58*	.93*											
2b. Communication	.64*	.52*	.59*	.54*	.60*	.94*	.85*										
2c. Risk Management	.65*	.54*	.60*	.58*	.56*	.94*	.83*	.84*									
2d. Involvement	.60*	.518	.54*	.51*	.56*	.93*	.79*	.82*	.84*								
3. Management Climate	.63*	.47*	.58*	.55*	.59*	.58*	.56*	.56*	.55*	.53*							
3a. Standards	.62*	.47*	.59*	.54*	.56*	.57*	.55*	.55*	.54*	.51*	.93*						
3b. Communication	.56*	.41*	.52*	.48*	.54*	.51*	.49*	.49*	.48*	.47*	.95*	.86*					
3c. Risk Management	.59*	.45*	.55*	.51*	.55*	.55*	.52*	.52*	.53*	.50*	.95*	.84*	.87*				
3d. Involvement	.60*	.46*	.54*	.53*	.56*	.57*	.54*	.54*	.52*	.52*	.94*	.82*	.85*	.88*			
4. Near Miss	-.043	-.018	-.03	-.04	-.06	-.04	-.04	-.02	-.02	-.06	-.03	-.03	-.03	-.02	-.02		
5. Minor Injury	-.039	-.026	-.04	.01	-.07	-.07	-.05	-.04	-.06	-.09*	-.04	-.05	-.03	-.04	-.04	.35*	
6. Injury	-.022	-.022	-.02	.00	-.07	-.04	-.02	-.03	-.04	-.05	-.01	-.02	-.02	-.01	.01	.37*	.55*

Table 12

Descriptive Statistics of all Variables (Year 2)

Variable	Mean*	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
1. Co-worker Climate	4.68	0.68	2.35	6.00	-0.42	0.16
1a. Standards	4.69	0.73	2.00	6.00	-0.39	0.24
1b. Communication	4.89	0.72	2.00	6.00	-0.74	0.66
1c. Risk Management	4.75	0.75	2.00	6.00	-0.42	0.04
1d. Involvement	4.38	0.90	1.40	6.00	-0.39	-0.12
2. Supervisor Climate	4.71	0.88	1.61	6.00	-0.78	0.58
2a. Standards	4.74	0.91	1.00	6.00	-0.79	0.75
2b. Communication	4.64	0.96	1.20	6.00	-0.71	0.43
2c. Risk Management	4.74	0.89	1.60	6.00	-0.76	0.56
2d. Involvement	4.73	1.01	1.00	6.00	-0.92	0.67
3. Management Climate	4.56	0.89	1.45	6.00	-0.59	0.06
3a. Standards	4.67	0.89	1.17	6.00	-0.70	0.34
3b. Communication	4.52	0.98	1.40	6.00	-0.63	0.00
3c. Risk Management	4.61	0.91	1.17	6.00	-0.56	0.10
3d. Involvement	4.42	0.99	1.00	6.00	-0.58	0.15
4. Near Miss	0.55	1.82	0.00	30.00	9.05	122.49
5. Minor Injury	0.67	1.86	0.00	31.00	8.57	117.86
6. Injury	0.11	0.45	0.00	6.00	6.49	60.93

*minimum = 1 maximum = 6

In order to be included in the analysis, each workgroup needed to contain at least 3 members. Data from participants with no workgroup code were also excluded. This resulted in 91 participants nested in 20 workgroups being removed in Year 1, and 216 participants nested in 31 workgroups being removed in Year 2. Overall, there were 95 workgroups in Year 1, and 75 workgroups in Year 2. Before data aggregation took place, ICC's were calculated to assess the homogeneity of climate perceptions. In Year 1, the ICC for the co-worker scale was 0.125 (12.5%), 0.136 (13.6%) for the supervisor scale, and 0.088 (8.8%) for the manager scale. In Year 2, the ICC was 11.09% for the co-worker scale, 0.109 (10.9%) for the supervisor scale, and 0.044 (4.4%) for the manager scale. Though the scores for the co-worker and supervisor scales indicated that there was sufficient homogeneity of perceptions, the manager scale ICC was lower, particularly in the second year. However, such a small ICC is not uncommon in the literature (e.g. Neal & Griffin, 2006), with an ICC as small as 0.01% being shown to increase the Type 1 error rate as high as .17% (Barcikowski, 1981). Hence, it was decided that an ICC of this size was not sufficient grounds against data aggregation. The data does suggest however that facility membership exerts a smaller effect on individual perceptions of management commitment to safety in comparison to the medium effect size of group membership on supervisor/co-worker perceptions.

A one-way analysis of variance using unaggregated data was performed to determine whether there was sufficient between group variance to justify aggregation. A respondent's workgroup was the independent variable when testing the co-worker and supervisor scales, while facility was the independent variable when testing the manager Scale. The dependent variable was the total safety climate score. Results indicated that all safety climate scales exhibited significant between group variance in Year 1, Co-worker Scale: F (95, 751) = 2.03, $p < .001$ ($\eta_p^2 = .227$), Supervisor Scale: F (95, 738) = 2.18, $p < .001$ ($\eta_p^2 = .244$), Manager Scale: F (10, 736) = 7.83, $p < .001$ ($\eta_p^2 = .097$). The results were similarly positive in Year 2, Co-worker Scale: F (75, 602) = 1.956, $p < .001$ ($\eta_p^2 = .218$), Supervisor Scale: F (75, 598) = 1.918, $p < .001$ ($\eta_p^2 = .216$), Manager Scale: F (10, 585) = 4.418, $p < .001$ ($\eta_p^2 =$

.071).These results coupled with the ICC's suggest a need to consider the safety climate perceptions as “shared”, and therefore requiring aggregation.

Since each workgroup and facility needed data in both years to be included in the analysis of predictive validity, those workgroups and facilities with data in only a single year were also removed from the dataset. This process resulted in 49 workgroups being included for the analysis of co-worker and supervisor safety climate predictive validity, and 9 facilities being involved in the analysis of manager safety climate predictive validity. Due to the rarity of injuries in the organisation, Poisson regression was performed using SPSS 18.0. Group size was controlled for by utilising an offset, which was the log of the workgroup's size.

Before any analysis took place, histograms were inspected to ensure safety outcomes had an approximately Poisson shaped distribution. While safety outcomes at the group level had an approximately Poisson shaped distribution (see Figures 14 and 15 in Appendix D), at the facility level the small sample size made interpretation difficult, with inspection of histograms, skewness and kurtosis statistics in fact suggesting that self-reported safety outcomes adhered to an approximately normal distribution (see Figures 16 and 17 in Appendix D). The Shapiro-Wilk test for both near misses and injuries at the facility level were non-significant, suggesting normality. However, given the potential inaccuracy of normality tests with a small sample size, coupled with the difficulty in determining the distribution of the data, it was cautiously decided to utilise a non-parametric test devoid of distributional assumptions for facility level analyses. Therefore, the relationship between manager safety climate in Year 1 and safety outcomes in Year 2 was assessed using Spearman's Rho correlation. Since it is not possible to have an offset controlling for group size with a correlation analysis, mean scores were used rather than total injury counts.

Inspection of possible outliers took place for the group level data, with examination of standardised residuals and influence statistics not detecting any outliers. A final test for the group-level analyses was determining whether equidispersion was present. Not accounting for inequality between the variance and mean can lead to an increased risk of Type 1 errors (Coxe, West, & Aiken, 2009). Determining the presence of equidispersion was achieved by inspecting the Pearson Chi-Square statistic divided by degrees of freedom. The statistic indicated that overdispersion was present and standard Poisson regression may not be appropriate. Hence, a number of different models in the Poisson family were tested and compared to determine best model fit. The models tested included the standard Poisson model, the overdispersed Poisson model and the negative binomial model. Nested model comparisons were conducted using the likelihood ratio test, while the Akaike's Information Criterion was used to compare the overdispersed Poisson model and the negative binomial model given they are not nested and thus cannot be compared using the likelihood ratio test. The negative binomial and overdispersed Poisson models provided more conservative estimates of standard error compared to standard Poisson regression, and provided a better fit to the data given they brought dispersion scores closer to one and were a better fit to the data as shown by the likelihood ratio test. Overall, the overdispersed Poisson model was the more accurate and parsimonious representation of the data given it accounted for the substantial overdispersion and achieved superior fit indices compared to the negative binomial model.

7.3.4 Regression Analyses

The results of the overdispersed Poisson regression analyses are presented in Table 14. As expected, supervisor safety climate in Year 1 was significantly negatively associated with self-reported near misses in Year 2, achieving a regression coefficient of -0.592. The 95% confidence interval ranged from -1.158 to -0.027, owing to the narrow range of scores and sizable standard error. The regression coefficient equates to a rate ratio of 0.55, (0.314 to 0.975), indicating that a mean score difference of 1 approximately equates to 45% less near misses experienced. The communication subscale additionally was significantly associated with self-reported near misses. The standards and involvement subscales fell marginally short of significance at the 0.05 level, with $p = 0.053$. As per the cross-sectional analyses, the scale and subscales did not significantly predict self-reported injuries.

The co-worker scale demonstrated negligible associations with both self-reported near misses and injuries. Its subscales also failed to demonstrate leading effects, with no subscale coming close to reaching significance. As such, the scale failed to provide any evidence of predictive validity.

The results of the Spearman's rho correlations, which examined the relationship between facility level (manager) safety climate in Year 1 and safety outcomes in Year 2, are presented in Table 14. Despite an appreciable correlation of -0.417 (r^2 = 0.174), the manager scale failed to demonstrate a significant association with self-reported near misses. The involvement subscale did however reach significance, with p = 0.050, and r^2 = 0.340. According to Cohen's (1988) effect size conventions, an r of .1 indicates a small effect, an r of 0.3 indicates a medium effect, and an r of 0.5 indicates a large effect. Hence, the manager scale was close to having a large effect, with 17.4% of the variability in self-reported near misses explained by differences in the mean manager safety climate score in a facility. The involvement subscale demonstrated a large effect, with 34% of the variability in self-reported near misses explained by differences in the subscale score. The other subscales did not demonstrate any significant lagged associations with reported near misses, and the scale and all subscales demonstrated negligible associations with self-reported injuries.

Spearman's rho correlations were also performed between manager scale scores and official organisational minor injury/injury data. Since there are large differences in the number of employees per facility, the total number of minor injuries/injuries was divided by the official numbers of employees per facility, thereby controlling for differences in facility size. Refer to Table A6 in Appendix C for a comparison of self-reported and official injury statistics for each facility in the organisation. Overall, official injury numbers tended to be lower than self-reported numbers, reflecting previous research in the safety climate literature that has demonstrate the prevalence of incident under-reporting (see Probst, Brubaker, & Barsotti, 2008).

Table 13

Relationship between Group Level Safety Climate in Year 1 and Self-Reported Safety Outcomes in Year 2 (N = 49)

	Near Miss	p Value	Injury	p Value
Co-worker Scale	-0.309 (0.398)	0.437	-0.012 (0.470)	0.979
Standards	-0.263 (0.380)	0.486	-0.095 (0.450)	0.832
Communication	-0.390 (0.426)	0.360	-0.154 (0.508)	0.762
Risk Management	-0.179 (0.370)	0.629	-0.145 (0.435)	0.738
Involvement	-0.245 (0.309)	0.427	0.217 (0.373)	0.561
Supervisor Scale	-0.592 (0.289)	0.040*	-0.502 (0.336)	0.135
Standards	-0.467 (0.241)	0.053	-0.419 (0.286)	0.143
Communication	-0.758 (0.287)	0.008*	-0.506 (0.338)	0.135
Risk Management	-0.364 (0.309)	0.239	-0.298 (0.359)	0.407
Involvement	-0.518 (0.268)	0.053	-0.559 (0.301)	0.064

* $p < 0.05$

Table 14

Spearman's Rho Correlations between Manager Safety climate and Self-Reported Safety Outcomes (N = 9)

	Near Miss Correlation Coefficient	p Value	Injury Correlation Coefficient	p Value
Manager Scale	-0.417	0.132	0.000	0.500
Standards	-0.483	0.094	-0.100	0.399
Communication	-0.233	0.273	0.167	0.344
Risk Management	-0.367	0.166	0.100	0.399
Involvement	-0.583	0.050*	-0.167	0.334

* $p < 0.05$

As seen in Table 15, the results echoed the self-reported statistics, with the scale not significantly correlated with minor injuries or injuries. Like the self-reported statistics, the involvement subscale demonstrated the strongest association with safety outcomes, achieving a sizeable correlation of -0.524 with injuries. According to Cohen's effect size conventions, this corresponds to a large effect size. Despite the sizeable yet non-significant results, once again owing to the inadequate sample size (N = 8), the results reflect favourably on the predictive validity of the manager safety climate scale. While manager safety climate demonstrated negligible associations with the self-reported injury outcome, the associations with official data was sizeable and in the anticipated direction. Overall though, the self-reported and official data was strongly correlated, with self-reported injury having a 0.571 correlation with official injury data, and self-reported minor injuries demonstrating a 0.548 correlation with official minor injury data. The association between self-reported and official injury statistics therefore represent a large effect. The strong association between self-reported and official safety outcome data supports the use of self-reported data as a valid indicator of actual safety outcomes, with the only downside of self-reported data appearing to be a slight underestimation of the relationship between safety climate and injuries.

Table 15

Spearman's Rho Correlations between Manager Safety Climate and Official Injury Statistics (N = 8)

	Minor Injury Correlation Coefficient	p Value	Injury Correlation Coefficient	p Value
Manager Scale	-0.190	0.326	-0.333	0.210
Standards	-0.286	0.246	-0.381	0.176
Communication	-0.262	0.265	-0.262	0.265
Risk Management	-0.238	0.285	-0.381	0.176
Involvement	-0.333	0.210	-0.524	0.091

Finally, the predictive validity of the co-worker scale when aggregated to the facility level was investigated (See Table A4, A5 in Appendix B). As per the analyses investigating the predictive validity of the manager scale, Spearman's rho was used. Associations were small, with two subscales demonstrating positive associations and two subscales demonstrating negative associations with self-reported near misses. The overall association between co-worker safety climate and self-reported near misses was 0.033, which is lower than the threshold for a small effect size according to Cohen's (1988) conventions. Hence, it can be surmised that there is a negligible association between co-worker safety climate and self-reported near misses at the facility level. Associations were slightly stronger with self-reported injuries, with three subscale demonstrating associations in the anticipated direction, with the overall association being -0.150. This would be considered a small effect size. Associations with official injury data provided similar results. Many of the correlation coefficients were not in the anticipated direction, with an overall correlation coefficient of 0.167 for minor injuries, and a medium effect size association of 0.381 with injuries. Therefore, both the self-reported and official data suggests that the co-worker scale has a negligible or inconsistent association with safety outcomes when aggregated to the facility level, with these analyses providing no evidence that the co-worker scale should be aggregated to the facility level instead of the workgroup level.

7.4 Discussion

This analysis tested the lagged effects of a multilevel safety climate survey. In line with Zohar's Multilevel Model of Safety Climate (Zohar, 2000; Zohar & Luria, 2005), the supervisor scale demonstrated significant leading associations with self-reported near misses the following year. The involvement subscale of the manager scale similarly demonstrated significant associations with subsequent self-reported near misses; however the total scale fell short of reaching significance due to an inadequate sample size. Therefore, the results provide tentative support for the use of multilevel safety climate surveys in the oil and gas industry. In the current objective, Zohar's model was extended to include perceptions of co-workers, however contrary to expectations the co-worker scale failed to demonstrate any significant lagged effects on any of the safety outcomes.

These results provide further evidence supporting Zohar's (2000; Zohar & Luria, 2005) conceptualisation of safety climate and his Multilevel Model of Safety Climate. While traditionally safety climate scales measured a number of distinct aspects of the organisational environment in a single scale operationalized at the individual level, the modern approach to safety climate heralded by Zohar operationalizes the construct at the aggregate level, reflecting the shared/nonindependent nature of safety climate perceptions. These aggregated perceptions of supervisor and manager commitment to safety have been demonstrated to predict safety outcomes in a number of studies (Neal and Griffin, 2006; Johnson, 2007; Zohar, 2000) with the current analysis the first to have a scale that conforms to Zohar's model and demonstrate associations with a safety outcome in an oil and gas context.

The results further demonstrate the central role that supervisors have in promoting safety within organisations. The significant leading effects of the supervisor scale demonstrated that groups which perceived their supervisor as having a low commitment to safety tended to be at higher risk of self-reported near misses the subsequent year. According to Zohar's model, this indicates that employees have developed behaviour-outcome expectancies from their interactions with their supervisor, and in those groups which perceive that safety has a high priority, individuals tend to behave in a safer manner and therefore are not exposed to as many potentially dangerous situations in comparison to groups in which safety is perceived to be of a low priority. Therefore, the results suggest that safety initiatives directed towards improving the commitment to safety of supervisors would be beneficial in improving safety outcomes within organisations, particularly given that this finding has now been demonstrated in multiple industries.

According to Zohar's Multilevel Model of Safety Climate (Zohar, 2000; Zohar & Luria, 2005), supervisors are an important source of behaviour-outcome expectancies since formal procedures do not cover every eventuality, meaning that there is supervisory discretion in the interpretation and enforcement of company procedures. It was expected that there would be similar discretion among co-workers, with supervisors not present at all times leading to differences among workgroups in their interpretation and adherence to policies and procedures. However, the co-worker scale did not demonstrate any significant lagged associations with the safety outcomes, which is in contrast to previous research which has espoused the important role of co-workers in promoting safety within organisations (e.g. Roy, 2003: Simard & Marchand, 1997). These results therefore corroborate the findings of the previous analysis, which found no significant cross-sectional associations between co-worker perceptions and safety outcomes. As previously mentioned, this is likely due to supervisors being a more palpable source of behaviour-outcome expectancies in comparison to co-workers because of their ability to punish/reward behaviour. However, in a high risk organisation such as the one studied, where there is a high degree of supervision present, less discretion may be present among co-workers which makes the weaker associations between co-worker safety climate and safety outcomes understandable. In organisations where there is a less hierarchical structure and less supervision in daily tasks (i.e. certain healthcare environments), group norms and co-worker perceptions may have a more influential role in comparison to perception of supervisors. For example, Hansen, Williams, and Singer (2010) found that the safety climate perceptions of frontline staff were related to hospital readmission, while the perceptions of the less involved management staff were not. Hence, further research is required to investigate whether co-worker safety climate has a more prominent role in different types of organisations before discounting it in safety climate research.

Though it is difficult to draw conclusions about the predictive validity of the manager scale due to the analytical problems encountered, the sizeable correlations between the scale/subscales and self-reported near misses were promising. While the small sample size likely prohibited the analyses from reaching significance, the association between manager safety climate and self-reported near misses had a medium to large effect size, while the association between the involvement subscale and self-reported near misses had a large effect size. Associations with official injury data cross-validated the self-report findings, with medium to large effects sizes similarly demonstrated. Given these promising findings, coupled with the predictive validity of the supervisor scale, the results overall support Zohar’s Multilevel Model of Safety Climate and provide an incentive for other organisations to utilise a multilevel framework in their measurement of safety climate. Given the statistical and methodological advantages of the multilevel approach, coupled with the ability to pinpoint interventions at particular behaviours at particular levels of the organisation, the benefits of a multilevel framework exceed the disadvantage of requiring a larger sample size, and the logistical and ethical implications of workgroup identification. As evidenced by the current analysis and Zohar's findings, a good base for scale development is the behaviourally inclined constructs of safety compliance and safety participation (Griffin & Neal, 2000), which Zohar and Luria (2005) refers to as active and proactive practices, and the current analysis refers to as standards and involvement. Zohar and Luria's scale also includes a subscale assessing declarative practices, which the current analysis assesses in the communication subscale. By listing behaviours that are reflective of Zohar's active, proactive, and declarative practices and are relevant to the organisation, other organisations can develop multilevel safety climate scales which can assist in the reduction of injuries to its employees.

In conclusion, the results of these analyses further demonstrate the central role of supervisors and managers in maintaining a safe working environment. These results support previous findings of Zohar and his Multilevel Model of Safety Climate (Zohar, 2000; Zohar & Luria, 2005), in which employees develop behaviour-outcome expectancies based on their perceptions of their managers and supervisor's commitment to safety. By utilising Zohar's model yet developing a new scale specific to the organisation, this analysis has demonstrated that Zohar's multilevel framework can be applied to the oil and gas industry and potentially other industries. Though the co-worker scale failed to demonstrate any significant associations with safety outcomes, this does not rule out an extension of Zohar's model to include perceptions of co-workers. Further research is required in less supervised/hierarchical organisations/industries to determine whether co-workers have a more influential role.

Chapter 8

Path Model Comparisons

8.1 Introduction

As evidenced by the lack of an agreement on a conceptual model for safety climate and the inconsistencies in findings relating to whether safety climate has a direct or indirect effect on safety outcomes, there is a lack of knowledge on the mechanisms in which safety climate affects safety outcomes. This is predominately due to the ubiquity of scale validation studies, with only a small number of researchers taking the next step by placing safety climate within some conceptual model and examining the relationships it has with other variables through procedures such as path analysis.

Out of the small pool of studies which have examined path models, most of them conduct these on the individual level (e.g. Neal, Griffin, & Hart, 2000; Rundmo, 2000; Huang, Ho, Smith, & Chen, 2006; Lu & Tsai, 2010; Christian, Bradley, Wallace, & Burke, 2010). While these analyses provide interesting insights into how individually operationalized safety climate may affect other variables, the strong possibility that relationships on the individual level do not carry over to the aggregate level (Kozlowski & Klein, 2000) prohibit generalisations to the wider safety climate literature.

Among those studies which have aggregated their data, results have been mixed. Johnson (2007) validated a path model whereby supervisor commitment to safety predicted safety behaviour, which in turn predicted injury frequency. These findings reflected the work of Zohar and Luria (2005), who found that the relationship between manager commitment to safety and safety behaviour was fully mediated by supervisor commitment to safety. Newman, Griffin, and Mason (2008), though not specifically using path analysis techniques, found a similar pattern of results in their examination of the antecedents of self-reported vehicle accidents. The authors found that fleet managers (which had a proximal supervisory role) had a direct influence on increasing the motivation to drive safely, in comparison to supervisors (which had a comparatively distal managerial role). Supervisor commitment to safety was only responsible for an interaction effect, with motivation to drive safely higher among employees who perceived both their fleet manager and supervisor valuing safety.

In comparison, Neal and Griffin (2006), found that management commitment to safety predicted safety motivation, which in turn predicted self-reported behaviour. While Neal and Griffin did not test the comparative importance of supervisors, their findings are in line with a substantial portion of the safety climate literature which place management commitment to safety as the central safety climate dimension (Griffin & Neal, 2000; Flin, 2006; Neal & Griffin, 2006; Seo, Torabi, Blair & Eliis, 2004; Zohar, 1980). Hence, there are contrasting views on the relationship safety climate has with safety outcomes , which is likely due to the differences in the scale used, the industry assessed, and the underlying conceptual model followed. These findings, therefore, suggest the need for further research, to determine whether management or supervisors are more influential in promoting a safe workplace.

The study by Zohar and Luria (2005) is particularly important given it is the only one to separate perceptions of supervisors and managers and examine both lagged and cross-level relationships with safety outcomes. While studies by Johnson and Newman and colleagues support Zohar and Luria's findings, no study to date has empirically tested these cross-level relationships using path analysis techniques or determined whether the pattern of relationships generalise to the oil and gas industry. Therefore, in the current analysis, an attempt will be made to replicate and extend upon Zohar and Luria's findings in the oil and gas context.

In addition to determining whether Zohar and Luria's findings generalise to the oil and gas industry, it will also be determined whether Zohar's Multilevel Model of Safety Climate can be extended to include perceptions of co-workers. While supervisors and managers undoubtedly play an important role in promoting safety within organisations, this does not prohibit further levels of the organisation being specified, particularly given research which has demonstrated the influence co-workers have on safe behaviour (Simard &Marchand, 1997; Roy, 2003; Zhou, Fang, &Wang, 2008).

In order to examine these cross-level and lagged relationships with safety outcomes, a number of nested multilevel path models will be compared (see Figure 8 to 12). In these path models, supervisor and co-worker safety climate will be aggregated to the group level while manager safety climate will be aggregated to the facility level. Model 1 will first be compared with the model in Model 2. This will provide an insight into whether individuals get injured because they develop behaviour-outcome expectancies based on observations of managers, supervisors, and their co-workers, or whether management commitment to safety filters down to supervisor and co-worker commitment to safety, and it is these more proximal group-level behavioural norms that an individual bases their own behaviour on. It is hypothesised that Model 2 will demonstrate superior fit indices given the findings of Zohar and Luria (2005), who found that the relationship between manager safety climate and safety behaviour was mediated by the more proximal supervisor safety climate. If alternatively Model 1 demonstrates superior fit indices, it suggests that the Neal and Griffin conceptualisation of safety climate, in which management directly influence employees, is the better representation of the data.

Hypothesis 4a: The model shown in Figure 9 will demonstrate superior fit indices compared to the model in Figure 8.

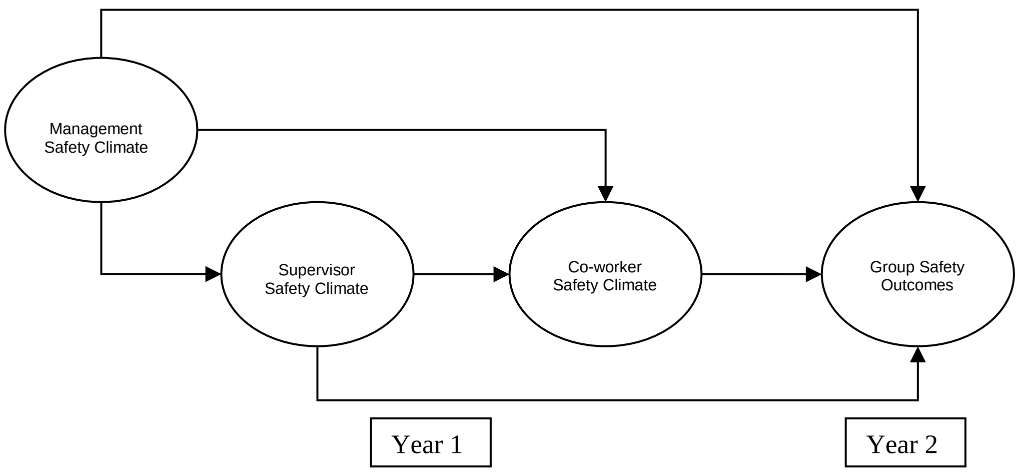

Figure 8. Model One: All paths included.

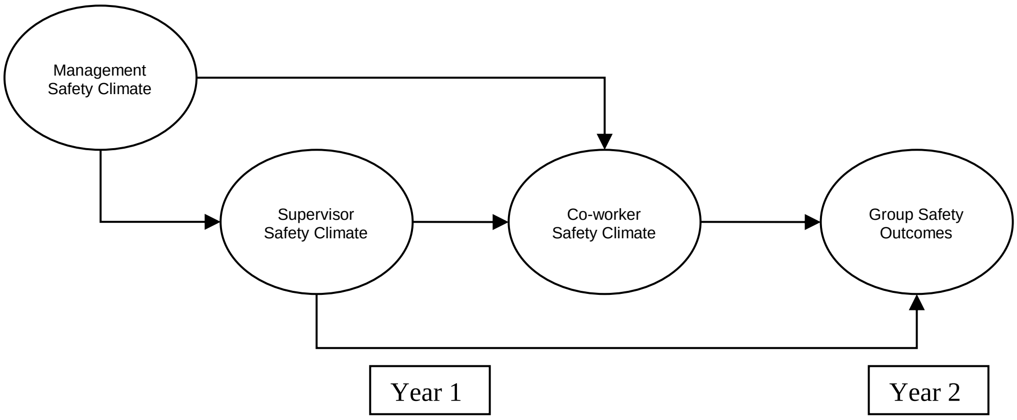

Figure 9. Model Two: Path between manager safety climate and safety outcomes removed.

Model 2 will then have its fit indices compared with Model 3. This will determine whether manager safety climate directly affects co-worker safety climate, or whether co-worker safety climate is the sole product of supervisor safety climate. It is hypothesised that Model 3 will demonstrate superior fit indices compared to Model 2 given that frontline employees are rarely in contact with managers, and so it is more likely individuals would develop behaviour-outcome expectancies based on the actions of those around them (i.e. supervisors and co-workers).

Hypothesis 4b: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model in Figure 9.

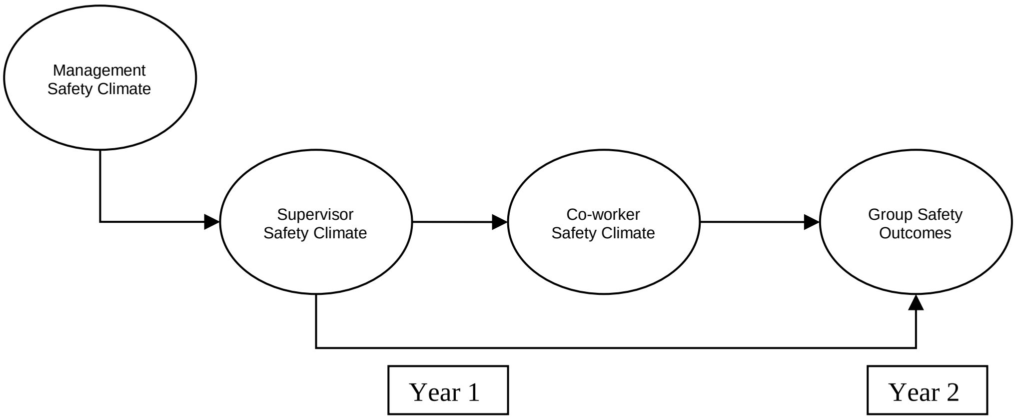

Figure 10. Model Three: Path between manager safety climate and co-worker safety climate removed.

The fit indices of the model in Model 4 will be compared to the model in Model 3. By comparing these two models it will be determined whether co-worker safety climate makes an important contribution to the prediction of employee safety outcomes as expected, or whether supervisor safety climate on its own adequately predicts employee safety outcomes.

Hypothesis 4c: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model seen in Figure 11.

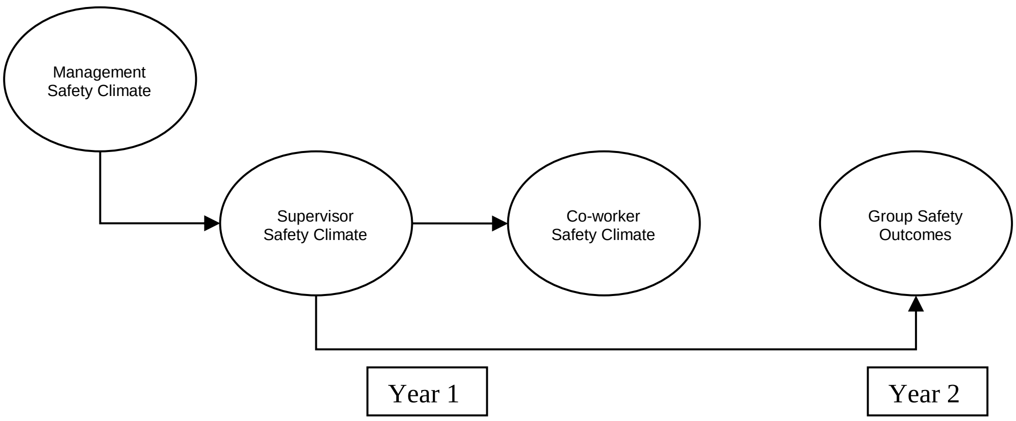

Figure 11. Model Four: Path between co-worker safety climate and safety outcomes removed.

Finally, Model 3 will be compared to Model 5. In Model 5, the relationship between supervisor safety climate and employee safety outcomes is mediated by co-worker safety climate. Since it has been found that the relationship between manager commitment to safety and safety behaviour is fully mediated by supervisor commitment to safety, it is possible that the same relationship may apply with supervisor commitment and co-worker commitment to safety. This relationship makes a certain amount of intuitive sense given that a workgroup's norms would be influenced by supervisor commitment to safety, with workgroup norms perhaps being the predominant influence on an individual's behaviour. For example, research by Wagenaar and Groeneweg (1987) demonstrated that an individual's behaviour is most predicted by the norms of the workgroup rather than the formalised rules and procedures. However, given the large amount of research in the safety climate literature espousing the importance of supervisor commitment to safety, coupled with the fact that employees in the organisation are in regular contact with supervisors and are thus likely to develop behaviour-outcome expectancies from them, Model 3 is hypothesised to demonstrate superior fit indices compared to Model 5.

Hypothesis 4d: The proposed model, as seen in Figure 10, will demonstrate superior fit indices compared to the model seen in Figure 12.

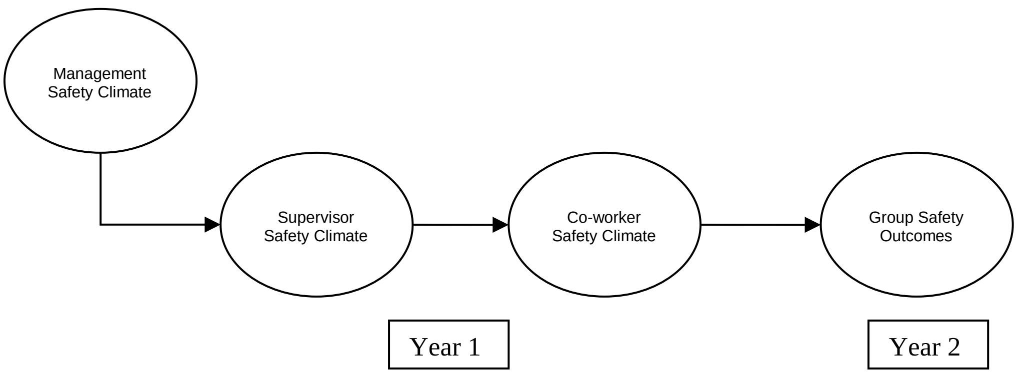

Figure 12. Model Five: Fully mediated model, with the path between supervisor safety climate and safety outcomes removed.

8.2 Method

Please refer to Chapter Four for a full description of participants, measures, and procedures. Due to sample size limitations, it was determined that multilevel path analyses would not be possible. There are a number of sample size rules of thumb for SEM, such as 10 participants per parameter (Kline, 1998) or having at least 100 participants (Hoyle & Kenny, 1999), and with multilevel analysis these participant numbers are required at each level. With only 11 'participants' at the organisational level, the sample size failed to come close to any generally accepted sample size metric. An attempt was made to determine whether a simpler multilevel mediation path model using SEM techniques (Preacher, Zyphur, & Zhang, 2010; Preacher, Zhang, & Zyphur, 2011) would converge in which the co-worker scale was not included, however as expected the model failed to converge due to the inadequate sample size.

Therefore, perceptions of management commitment to safety were aggregated to the group level in order to maximise sample size, akin to research by Neal and Griffin (2006) and Newman, Griffin, and Mason (2008). Since this operationalization does not adhere to Zohar's Multilevel Model of Safety Climate, additional cross-validation analyses will be conducted in order to substantiate any findings and provide an opportunity to relate results to Zohar's theoretical framework. The cross-validation analyses will be as followed:

1. Path model comparisons using cross-sectional data from Year 1 (N = 96).

2. Path model comparisons using cross-sectional data from Year 2 (N = 75).

3. Path model comparisons using safety climate data from Year 1 and safety outcome data from Year 2 (N = 49)

4. Multilevel mediation analyses using the three step Baron and Kenny (1986) method to replicate Zohar and Luria's (2005) findings and to substantiate path analysis results (N = 96).

8.3 Results

8.3.1 Cross-Sectional Path Analyses

All path analyses were conducted using the EQS 6.1 program (Bentler, 2006), with path models entered as seen in Figure 13. Workgroup safety climate means were used for the manager, supervisor, and co-worker scales, with a factor created describing self-reported incident frequency (measured through workgroup near miss, minor injury, and injury mean). Self-reported injuries and minor injuries were freely estimated paths, while the self-reported near miss path was fixed at one to allow estimation of error variance. Though the sample size was not ideal, particularly given the number of parameters in the model, other aspects of assumption testing did not present any significant problems. Data was skewed, particularly the dependent variable, with Mardia's normalised indicating a violation of multivariate kurtosis, however robust estimates were used which corrects for non-normality. Inspection of cases which contributed to multivariate kurtosis detected four outliers, which were removed. Multicollinearity and singularity was not evident as EQS was able to invert the matrices, with no convergence problems.

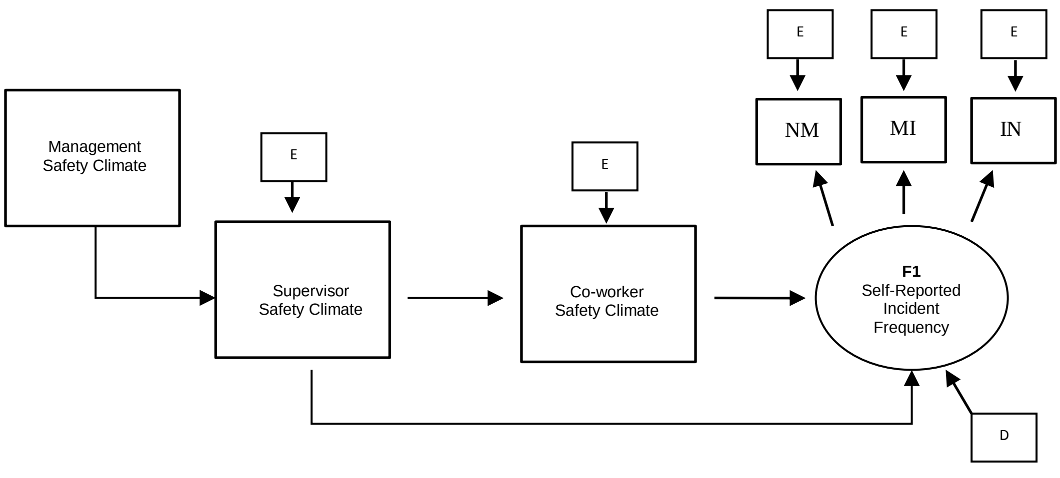

Figure 13. Measurement model as entered in EQS for model three. NM = Near Miss, MI = Minor Injury, IN = Injury, E = Error, D = Dispersion (error).

Firstly, in order to test Hypothesis 4a, Model 1 was compared to Model 2. Model 2 achieved superior fit indices, with the comparative fit index (CFI) of 0.915 in Model

1, compared to 0.938 in Model 2. The non-normed fit index (NNFI) was 0.788 for Model 1, compared to 0.868 in Model 2. Hence, Model 2 surpassed the recommended value of 0.85 (Hu & Bentler, 1999) for the NNFI, while Model 1 fell short. However, the root mean-square error of approximation (RMSEA) for both models indicated inadequate model fit, with Model 1 attaining 0.136 (0.056 to 0.217) and Model 2 attaining 0.107 (0.010 to 0.186). With a liberal cut-off of 0.80 (Browne & Cudeck, 1993), and a conservative cut-off of 0.050 (Hu & Bentler, 1999), these models were therefore not close to achieving good model fit. The RMSEA does have a tendency to underestimate fit in small sample sizes (Hu & Bentler), hence this might have played a role in the poor fit indices achieved and the large confidence intervals.

While the chi-square statistic is used for the assessment of model fit when normality is assumed, other indicators are required when normality is violated; hence EQS provides a number of distribution-free residual based statistics. The Yuan-Bentler residual-based test statistic (Yuan & Bentler, 1998), which is a modification of Brownes (1982; 1984) residual-based test that has been extended for use in smaller sample sizes, indicated poor model fit for Model 1, with χ^2 = 16.200, $p < 0.05$. For Model 2 the test indicated good model fit, with χ^2 = 11.494, p > 0.05. The Yuan-Bentler residual-based F-statistic (Bentler & Yuan, 1999) displayed a similar pattern of results, with Model 1 demonstrating poor model fit, F (6, 85) = 3.117, $p < 0.05$ and Model 2 displaying good model fit, F (7, 84) = 1.760, $p > 0.05$. This statistic is considered to perform the best at small sample sizes (Bentler, 2006); with the results overall clearly demonstrate the superiority of Model 2. AIC results further provided evidence of Model 2's superiority, with Model 1 achieving an AIC of 3.92, as compared to Model 2 which achieved an AIC of 0.19. Hence, Hypothesis 4a was supported, with Model 2 exhibiting superior fit indices compared to Figure 1.

Model 2 was then compared to Model 3 in order to test Hypothesis 4b. The approximate fit indices for Model 3 were appreciably lower than Model 2, with CFI = 0.735, NNFI = 0.503, and RMSEA = 0.207 (0.144 to 0.273). The residual-based tests of model fit similarly suggest the inadequacy of the model shown in Model 3, with

$\chi^2 = 22.251$, $p < 0.05$, and $F(8, 83) = 3.420$, $p < 0.05$. Overall, these findings indicate the path linking manager safety climate and co-worker safety climate is important, and more closely reflects the 'true' model of the data. Hence, Hypothesis 4b was not supported, with Model 2 demonstrating superior fit indices compared to Model 3.

In order to test Hypothesis 4c, Model 3 was compared to Model 4, which ascertains the importance of the path linking co-worker safety climate to safety outcomes. While Model 3 displayed overall poor model fit, Model 4 displayed substantially worse model fit (CFI = 0.662, NNFI = 0.437, RMSEA = 0.221 (0.161 to 0.282)). Both residual-based tests were also significant, further indicating poor model fit, $\chi^2 = 24.580$, $p < 0.05$, $F(9, 82) = 3.438$, $p < 0.05$. The findings therefore indicate the importance of co-worker perceptions in the prediction of safety outcomes, supporting Hypothesis 4c.

Lastly, in order to test Hypothesis 4d, Model 5 was compared to Model 3, which determines whether a fully mediated model is present and tests the importance of a direct path linking supervisor safety climate to safety outcomes. Both residual-based tests were significant $\chi^2 = 29.219$, $p < 0.05$, $F(9, 82) = 4.403$, $p < 0.05$, with CFI = 0.627, NNFI = 0.379, and RMSEA = 0.232 (0.172 to 0.293). The results therefore suggest the importance of the path linking supervisor safety climate to safety outcomes, with a fully mediated model not supported. Hence, Hypothesis 4d was supported, with Model 5 demonstrating inferior fit indices compared to Figure 3.

Overall, Model 2 was found to have the best fit indices out of all the models, and despite the high RMSEA, it overall demonstrated adequate model fit. In an exploratory effort to determine whether any parameters could have been added to improve model fit, the Lagrange Multiplier (LM) test was performed. The LM test indicated that model fit could be improved by the addition of a path between manager safety climate and self-reported near misses. Given that the path between these variables was theoretically reasonable, the parameter was added and fit indices recalculated. The new model (Model 6) demonstrated superior model fit compared to the unmodified model (Model 2), with both residual based tests non-significant, $\chi^2 = 7.875$, $p > 0.05$, F (6, 85) = 1.360, $p > 0.05$. Other fit indices demonstrated excellent model fit, with CFI = 0.979, NNFI = 0.948, RMSEA = 0.067 (0.000 to 0.162). AIC comparisons also indicated that model 6 was superior, achieving an AIC of -0.36 in comparison to the 0.19 achieved by Model 2. All fit indices therefore suggested that Model 6 was a good representation of the data, with only the RMSEA being sub-optimal due to its large confidence interval. Figure 14 presents the best fitting structural model, with standardised parameter estimates added. Robust estimates were used for the estimation of standard error and the significance of the estimates due to the non-normality of the data. A comparison of fit indices for all models can be found in Table 16.

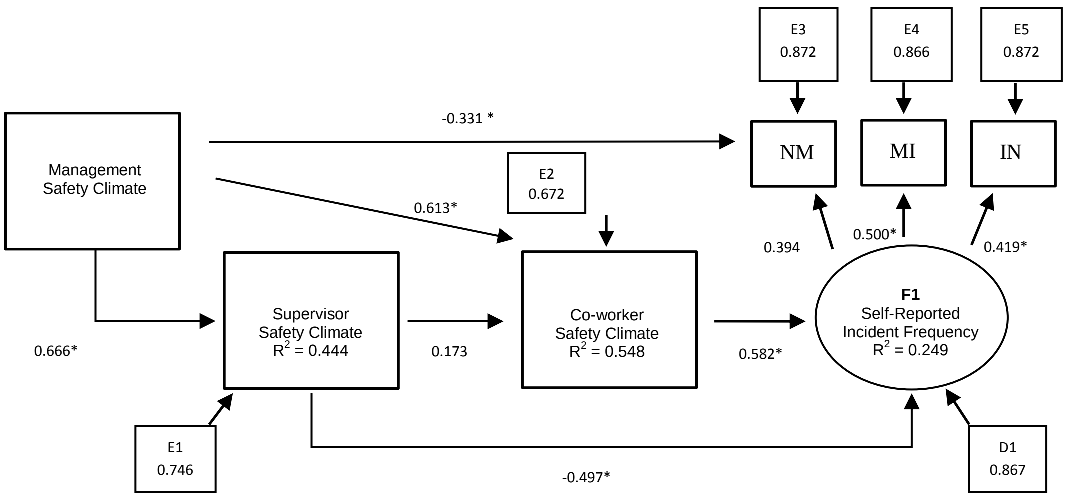

Figure 14. Structural model for best fitting model (Model 6).

Self-reported minor injury and injury loaded significantly on the self-reported injury frequency factor, indicating that despite their low frequency in comparison to self-reported near misses, they are all an adequate representation of self-reported injury frequency. While the near miss variable appears to load non-significantly on the self-reported injury frequency factor, its non-standardised parameter estimate was fixed at 1.00, meaning no test of significance took place. The path between supervisor safety climate and co-worker safety climate was non-significant, with manager commitment to safety being the predominant influence, reflecting the fact that Model 2 had superior fit indices compared to the Model 3.

Table 16

Comparison of Select Fit Indices for Path Models

	Yuan-Bentler Residual-Based F Statistic	CFI	NNFI	RMSEA
Cut-Off Criteria		= / >.85	= / >.85	= / <.08
Model 1	3.117*	0.915	0.788	0.136 (0.056 to 0.217)
Model 2	1.760	0.938	0.868	0.107 (0.010 to 0.186)
Model 3	3.420*	0.735	0.503	0.207 (0.144 to 0.273)
Model 4	3.438*	0.662	0.437	0.221 (0.161 to 0.282)
Model 5	4.403*	0.627	0.379	0.232 (0.172 to 0.293)
Model 6	1.360	0.979	0.948	0.067 (0.000 to 0.162)

Note. * indicates significance at $p < 0.05$. Non-significance indicates good model fit.

In the prediction of the self-reported injury frequency factor, both supervisor safety climate and co-worker safety climate had a significant relationship. While the relationship between supervisor safety climate and the self-reported injury frequency factor was in the negative direction as expected, the relationship between co-worker safety climate and the self-reported injury frequency factor was positive. This counter-intuitively indicates that as co-worker commitment to safety increases, the possibility of becoming injured increases. The R^2 of the self-reported injury frequency factor was 0.25, indicating that 25% of the variability in self-reported ‘accident’ events was explained by co-worker and supervisor safety climate scores.

8.3.2 Cross-validation of results

Particularly when exploratory analyses such as the LM test are performed, cross-validation of results is recommended. This is because when modifying models based on statistical criteria such the LM test, there is the possibility of “over-fitting” a model, in which the specific pattern of relationships between variables become sample specific (Byrne, 2006). Therefore, the model fit of Model 6 was examined in two additional datasets. Firstly, since the previous analyses have only involved Year 1 data, the model was assessed using the data in Year 2. Secondly, the model was assessed using climate data from Year 1 and safety outcome data from Year 2, in order to examine predictive relationships. As per the previous analysis, outliers were first screened by inspecting cases which contributed to multivariate kurtosis, resulting in one outlier being removed from the Year 2 data, and four outliers being removed from the Year 1 → Year 2 data.

The results of the cross-validation using Year 2 data supported the previous finding that the Model 6 model represented a good fit to the data (see Table 21). Both the Yuan-Bentler residual based statistic and the Yuan-Bentler residual-based F statistic were highly non-significant, $\chi^2 = 4.894$, $p > 0.05$, $F\ (6, 69) = 0.815$, $p > 0.05$. Fit indices also suggested excellent model fit, with CFI = 1.000, NNFI = 1.017, RMSEA = 0.000 (0.000 to 0.142). Parameter estimates also supported the previous findings. Self-reported minor injuries and injuries both significantly loaded on the self-reported incident frequency factor, further demonstrating that they were a reliable measure of self-reported injury frequency. While the path between supervisor safety climate and co-worker safety climate in the previous path analysis was non-significant, in the current analysis the path was significant. In comparison to the path models using Year 1 data, this result suggests that supervisors may play a role in influencing the commitment to safety of co-workers.

The parameter estimates provide further evidence of the role managers have in influencing the commitment to safety of the workforce, with significant paths to supervisor safety climate and co-worker safety climate. As per the previous path analysis, supervisor safety climate significantly predicted self-reported injury frequency, while the path between co-worker safety climate and the self-reported injury frequency factor was non-significant, highlighting the anomalous nature of the counter-intuitive results arising from Year 1 data. Similarly, the path between manager safety climate and self-reported near misses was non-significant, which suggests that this modification was sample specific. The non-significant association may also reflect the overall weakening of association between safety climate and safety outcomes in Year 2 data. The self-reported injury frequency factor achieved an R^2 of 0.25 in Year 1, while in Year 2 it was considerably smaller, with $R^2 = 0.098$. Hence, the model explained 25% of the variance using Year 1 data, while in Year 2 the model explained only 9.8% of the variance. Standardised parameter estimates for this model can be seen in Figure 15.

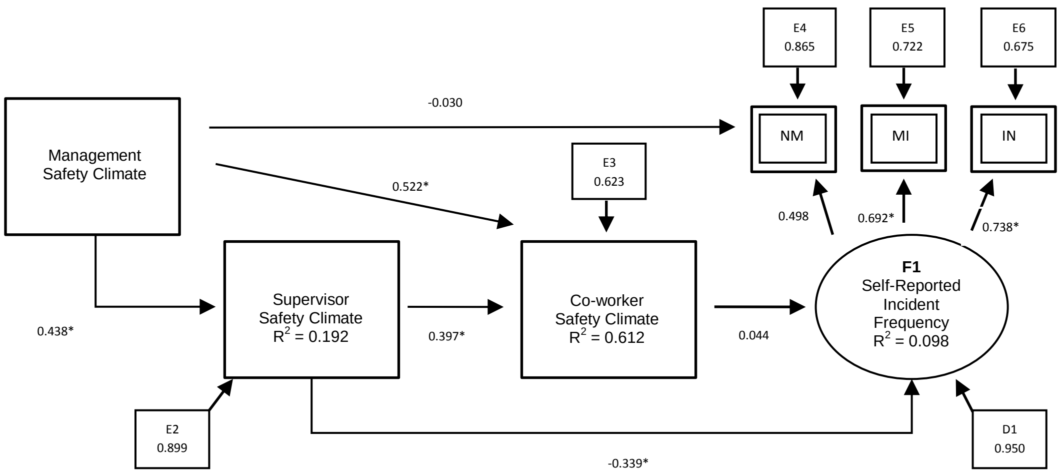

Figure 15. Structural equation model for Model 6 using Year 2 data.

As a secondary cross-validation, the fit indices of Model 6 were assessed using safety climate data from Year 1 and safety outcomes data from Year 2. This similarly demonstrated that the model was a good representation of the data, with both Yuan-Bentler residual-based test statistics being non-significant, with $\chi^2 = 5.859$, $p > 0.05$, $F(6, 39) = 1.002$, $p > 0.05$. The fit indices were also generally demonstrative of excellent model fit, with CFI = 0.972, NNFI = 0.931, RMSEA = 0.091 (0.000 to 0.227). Only the RMSEA fell short of its recommended cut-off, however the very small sample size (N = 45) may be the primary contributor of its high score and associated large confidence interval. Parameter estimates were also generally similar to the previous path analyses. Self-reported minor injury and injury had a strong yet non-significant association with the self-reported incident frequency factor, with the high standard error of the parameter estimates indicating that the low sample size may have been a factor. Supervisor safety climate demonstrated a significant association with the self-reported incident frequency factor, with co-worker safety climate falling slightly short of a significant association. Manager safety climate was once again a powerful predictor of supervisor safety climate and co-worker safety climate, with results aligning with the original path analysis in that the relationship between supervisor safety climate and co-worker safety climate was non-significant. Additionally, the added path between manager safety climate and self-reported near misses was significant, therefore providing evidence that the modification was warranted. The overall R^2 of the self-reported injury factor indicated a large effect size, with $R^2 = 0.350$. Standardised parameter estimates with significance calculated through robust standard errors can be seen in Figure 16.

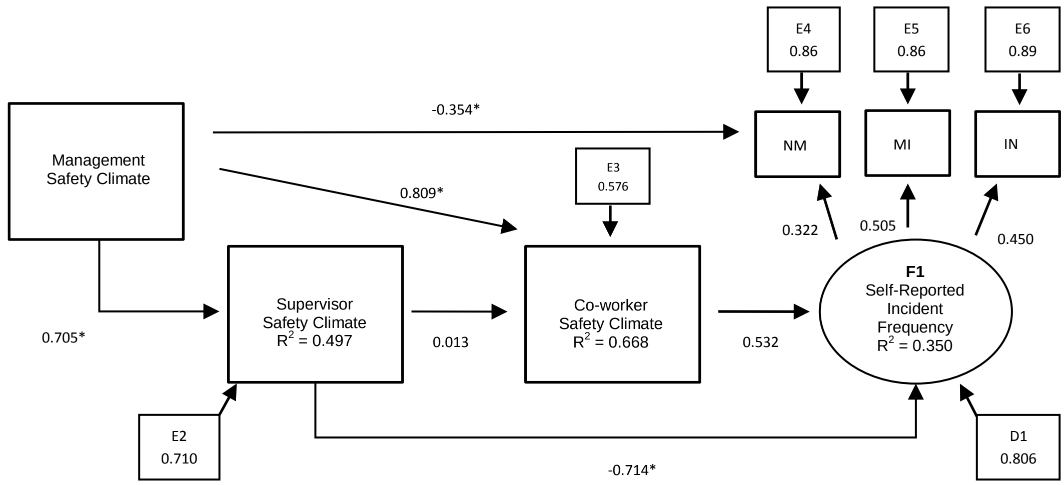

Figure 16. Structural equation model for Model 6 using Year 1 → Year 2 data.

Though there was overall similar results for the two cross-validations, some of the findings were not congruent. The strong associations between manager safety climate and lower levels of the organisation were supported throughout, in addition to the link between supervisor safety climate and the self-reported incident frequency factor. Both cross-validations demonstrated that co-worker safety climate was not significantly associated with the self-reported incident factor, providing evidence that the significant positive association found using Year 1 data was anomalous However, it should be noted that the relationship between co-worker safety climate and safety outcomes in the secondary cross-validation was still positive, and overall suggests that co-worker safety climate is not a viable predictor of safety outcomes at the group level. In the Year 1 data and one of the cross-validations, the link between supervisor safety climate and co-worker safety climate was not significant, providing an inconclusive indication that supervisor safety climate does not affect co-worker safety climate at the group level. Similarly, the added path between manager safety climate and near misses was supported by one cross-validation and not the other, thereby providing limited support for the path's addition.

Table 17

Fit Indices for Model 6 Using Data from Year 1, Year 2, and Year 1→ Year 2

	Yuan-Bentler Residual-Based F Statistic	CFI	NNFI	RMSEA
		= / >.85	= / >.85	= / <.08
Year 1	1.360	0.979	0.948	0.067 (0.000 to 0.162)
Year 2	0.815	1.000	1.017	0.000 (0.000 to 0.142)
Year 1→ Year 2	1.002	0.972	0.931	0.091 (0.000 to 0.227)

8.3.3 Mediation Analyses

Due to manager safety climate being assessed at the group level, it was decided to cross-validate the key path analysis findings using multilevel mediation techniques methodologically and theoretically consistent with Zohar's Multilevel Model of Safety Climate. The key finding to be cross-validated will be whether the relationship between manager safety climate and safety outcomes is mediated by supervisor safety climate, as observed by Zohar and Luria (2005) and suggested by the path analysis results. If previous analyses suggested that co-worker safety climate predicted safety outcomes, it would have also been tested whether the relationship between supervisor safety climate and safety outcomes was mediated by co-worker safety climate. However, both cross-validation path analyses and previous regression analyses have indicated that in this organisation co-worker safety climate has a lesser role in the prediction of safety outcomes compared to other levels of the organisation and so this mediation analysis will not be attempted.

The mediation analysis was conducted with MLwiN 2.2 (Rasbash et al., 2009), using data from Year 1, with this data chosen to maximise sample size. As per Zohar's Multilevel Model of Safety Climate, supervisor safety climate was aggregated to the workgroup level, while manager safety climate was aggregated to the facility level. Logistic regression was used in the association between safety climate and safety outcomes, with a logit link function selected and random intercepts included. For the association between manager safety climate and supervisor safety climate, standard multilevel regression procedures were used given the absence of a dichotomous outcome variable. Examination of histograms and normality statistics for the aggregated supervisor and manager scale scores indicated that the data was approximately normal. Models were first computed using 1st order MQL approximation, from which it was determined whether a random slope was required. Second-order PQL approximation was then used, with this process resulting in less biased estimates and less chance of convergence problems (Rashbash et. al., 2009). Standardised residuals and influence diagnostics were inspected to determine the presence of any extreme values, with one outlier being removed at the group level. Significance was calculated via the Wald test, which employs a chi-square distribution.

To test mediation, the three-step Baron and Kenny (1986) method was employed. Firstly, manager safety climate needs to be significantly associated with safety outcomes. Then manager safety climate must be significantly associated with supervisor safety climate. Lastly, the relationship between manager safety climate and safety outcomes should be greatly reduced (indicating partial mediation) or non-existent (indicating complete mediation) when controlling for supervisor safety climate. Contrary to expectations, the difficult to interpret results only partially supported a mediation process taking place. While manager and supervisor safety climate individually predicted self-reported near misses as previously found, when both levels of analysis were entered into the regression equation, the variance of the intercepts at the facility level could not be estimated (i.e. became zero). A printout of this analysis can be found in Appendix E. Twisk (2006) states that the inability of MLwiN to accurately estimate this random facility level intercept indicates that it is unimportant. In other words, in the prediction of supervisor safety climate or safety outcomes, differences between workgroups are far more important than differences between facilities (such as manager safety climate). Though these analyses do support the notion that supervisors play an important and direct role in promoting safety, the lack of facility level variance in the prediction of supervisor safety climate via manager safety climate prevents a mediation model from being fully supported.

8.4 Discussion

The path analyses provided a number of interesting results that generally reflect the findings of Zohar and Luria, despite some hypotheses not being supported. The important finding was that supervisor safety climate was the most important influence on safety outcomes, reflecting Zohar and Luria's study which found that the relationship between manager safety climate and safety outcomes was mediated by supervisor safety climate. Though a full multilevel mediation model was not supported by subsequent analyses, the path analyses demonstrated that a path between manager safety climate and the self-reported injury frequency factor resulted in a poor fitting Model 1, in comparison to the superior fit indices of Model 2 in which only supervisor and co-worker safety climate were associated with safety outcomes (refer to Figure 8 and 9).

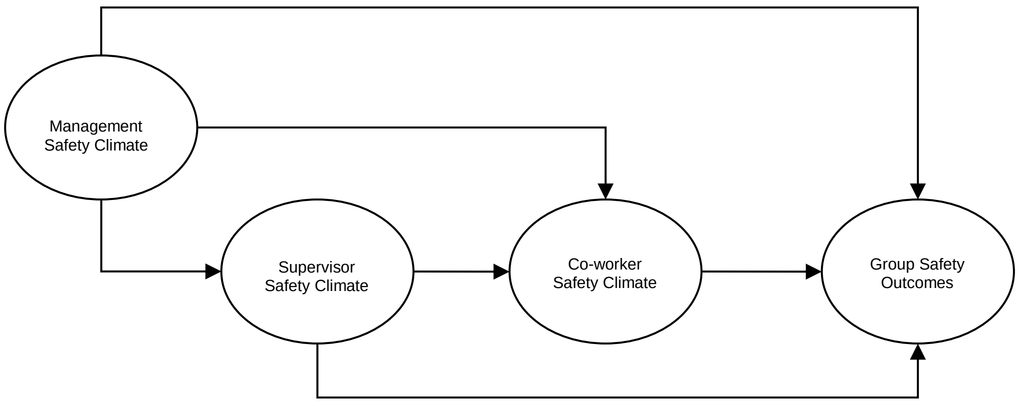

Figure 8. Model One: All paths included.

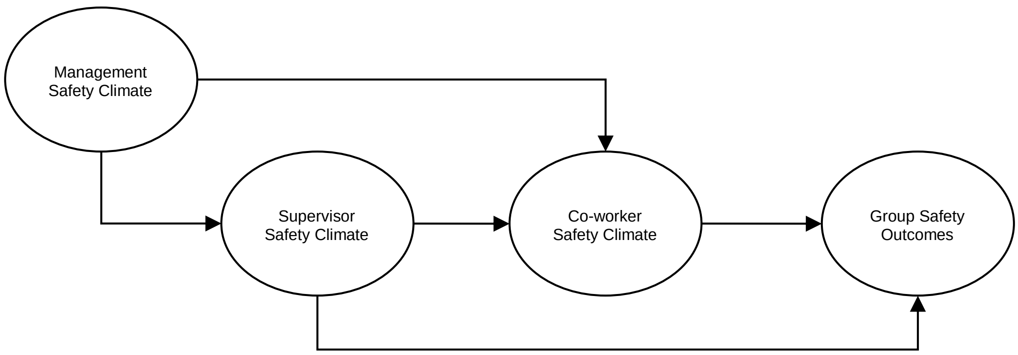

Figure 9. Model Two: Path between manager safety climate and safety outcomes removed.

Though the model in which a path was added between co-worker safety climate and safety outcomes demonstrated better fit, in both cross-validation attempts the parameter estimates were slightly positive and non-significant. Hence, for the sake of parsimony, this path could likely be removed due to the consistent evidence that co-worker perceptions at the group level have a negligible impact on safety outcomes. Overall, other than the unexpected path between manager safety climate and co-worker safety climate, the results are overall consistent with that of previous studies in this thesis, and of other studies in the literature which have drawn upon Zohar's conceptualisation of safety climate. Though some of the analyses need to be interpreted with caution, they overall suggest that the mediating role of supervisors is generalizable to the oil and gas industry, and therefore not limited to the manufacturing context wherein Zohar has tested all of his hypotheses.

Before this analysis, the only other non-Zohar investigation into the separate effects of manager and supervisor commitment to safety has been by Newman, Griffin, and Mason (2008). Newman and colleagues found that fleet manager safety climate was the predominant influence on safety, with supervisor safety climate having no direct effect but interacted with fleet manager safety climate to increase overall motivation to drive safely. Given that fleet managers may play a proximal supervisor-like role and supervisors play a distal management-like role in the driving context, the results of the current analysis are therefore in line with Zohar and Luria. Importantly, the context of these three studies is extremely different, yet the results are similar. While Zohar and Luria and the current analysis are in the manufacturing and oil and gas industries, which would likely have similar organisational structures, in the driving context the fleet manager distributes keys and possibly alerts employees to safety standards and issues. However, unlike supervisors in the previously mentioned contexts the fleet manager does not have authority over drivers and therefore does not reward/punish behaviour. Hence, despite large differences in the organisational context and supervisory role, what these studies demonstrate is that the central importance of a proximal, supervisory figure in promoting safety is a generalizable finding, contrasting with traditional safety climate research (e.g. Neal & Griffin, 2006) which has focused on management commitment to safety.

What make the generalizability of the findings even more important are the large differences in the operationalization of safety climate in the three studies. While all studies used different scales, Zohar and Luria and the current analysis had very similar subscales and behaviour-based wording of the items. In contrast, Newman and colleagues used Neal and Griffin's (2006) shorter scale for their assessment of safety climate, which assesses a general perception of commitment to safety rather than specific behaviours. Secondly, while Zohar and Luria assessed manager safety climate at the organisational level, reflecting the shared perceptions of management, both Newman and colleagues and the current analysis measured managers and supervisors at the group level. Despite these substantial differences in operationalization, the overall pattern of results was highly similar; suggesting that the increased importance of a proximal supervisory figure in comparison to a distal management figure in promoting a safe workplace is a relatively robust effect. While past research has made apparent that safety climate at the individual level displays a different pattern of results at the aggregate level (Kozlowski & Klein, 2000), the findings tentatively suggest that the same between-level inconsistency does not plague comparisons between manager safety climate measured at the group or organisational levels. In practice, this suggests that researchers who do not have access to a large pool of organisations can assess manager safety climate at the group level, with some confidence that their findings can still be generalised. Though level-of-analysis did not affect the relationship between manager/supervisor safety climate and safety outcomes, it may have affected the relationship between supervisor safety climate and co-worker safety climate. In contrast to hypotheses, the best fitting path model and one of the cross-validations showed that only manager safety climate predicted co-worker safety climate. It is unknown whether this relationship would hold if manager safety climate was aggregated to the facility level , and given the absence of other research exploring this relationship, the findings must be interpreted with caution.

In addition to further supporting the mediated relationship between manager safety climate and safety outcomes, comparisons between the path models and examination of parameter estimates provide some compelling results. While supervisor safety climate clearly has a direct influence on safety outcomes, the path analysis demonstrates the important role of management as an antecedent of climates lower in the organisation. In addition to its strong association with supervisor safety climate, it was also the primary predictor of co-worker safety climate. In comparison, supervisor safety climate had far weaker associations with co-worker safety climate, with the association between supervisor safety climate and co-worker safety climate reaching significance in only the Year 2 data. This was an unexpected finding, as it was assumed that supervisors, with their more proximal role in rewarding/punishing behaviour and communicating safety concerns, would be a more important influence on group norms and therefore the co-worker safety climate. While co-worker safety climate was not associated with safety outcomes, highlighting the importance of the supervisory role in shaping behaviour, it demonstrates that if employees perceive that their manager is committed to safety, they generally feel their workplace is more committed to safety. The path added through the LM test between manager safety climate and self-reported near misses similarly indicate that management commitment to safety may promote an overall perception of safety within an organisation, which is separate from the direct prediction of injuries. Given that management commitment to safety is predictive of job satisfaction, organisational commitment, and job performance (Michael, Evans, Jansen, & Haight, 2005), its ability to travel down through the organisation, as shown through the path analyses, may have positive outcomes for the organisation that go beyond safety.

The results of the multilevel mediation analyses were also contrary to expectations. Though earlier studies have demonstrated that manager and supervisor safety climate predicted self-reported near misses in isolation, when both levels were included in the same equation, the facility level variance of the intercepts were not able to be estimated. While this result is generally supportive of previous research and the path analyses when taken at face value, given it demonstrates that supervisors are much more important than managers at predicting safety outcomes, the results need to be interpreted with caution. While Twisk (2006) states that the inability to estimate variance of the intercepts indicates that the level is unnecessary, another possible explanation could be that the inadequate sample size at the facility level (N = 11) prevented accurate estimation. This alternate interpretation is supported by the inability of manager safety climate to predict supervisor safety climate, with the inability to estimate the facility level variance of the intercepts suggesting that facility level variables (such as manager safety climate) do not predict supervisor commitment to safety. This finding contrasts with the path analysis results, Zohar and Luria (2005), and a large body of research which has shown climate and culture to stem from management (Griffin & Neal, 2000; Hofstede et al., 1993; Neal & Griffin, 2006; Seo et al., 2004). Hence, while the sample size of the path analyses was likely adequate since the program was able to distinguish between poorly and well-fitting models (Bentler, 2006), a larger sample size was required for the multilevel mediation analyses.

In conclusion, results of the current analysis support the mediation model tested by Zohar and Luria (2005). The model in which a path existed between manager safety climate and safety outcomes demonstrated inferior fit indices to one in which this path was removed. This analysis contributed to the literature by demonstrating that Zohar and Luria's mediation model generalises to the oil and gas industry. It additionally showed that the operationalization of manager safety climate at the group level does not result in a different pattern of results compared to the organisational level, with the results not only reflecting Zohar and Luria, but Newman and colleagues, whose safety climate scales were worded with a less behavioural emphasis. The results suggest that this non-behavioural wording of the safety climate scales by Newman and colleagues and Neal and Griffin (2006) may have contributed to the weaker associations that safety climate had with safety outcomes in their studies. Finally, this analysis again failed to find evidence that co-worker safety climate influences safety outcomes. The results support Zohar's Multilevel Model of Safety Climate, which found that supervisors were the main influence on behaviour due to their proximity and ability to punish/reward/communicate to employees.

Chapter 9

Objective Five:

Comparisons between Safety Climate Operationalized at the Individual and Aggregate Level

9.1 Introduction

Like its parent term, organisational climate, safety climate has historically suffered from inconsistency in its definition, conceptual boundaries, and operationalization. While some of this inconsistency may be the product of the rapid evolution of the construct in the years since it was first developed, its links to organisational climate may be another contributing factor. When Zohar (1980) introduced the term safety climate, it was described as a particular type of organisational climate, consisting of some shared set of cognitions concerning safety, in particular management commitment to safety. Even at this formative stage, safety climate was described and operationalized as an aggregate variable. Zohar referred to 'shared cognitions' and assessed criterion validity by aggregating scores to the facility level. However, other authors have since measured safety climate at the individual level (e.g. Rundmo, 1994; Mearns, Flin, Gordon, & Fleming, 2001; Neal, Griffin, & Hart, 2000; Seo et al., 2004; Vinodkumar & Bhasi, 2009). Out of the 32 safety climate studies included in Christian and colleagues (2009) meta-analysis, 18 operationalized safety climate at the individual level, while in my own review of the literature over the past decade, approximately one third of studies operationalized safety climate at the individual level. This variation in level of analysis reflects similar ambiguity in the wider organisational climate literature, whereby researchers either categorised climate as being an attribute of the organisation (organisational climate) or the individual (psychological climate) (James & Jones, 1974). Despite pleas from some authors (e.g. Glick, 1985) to use the correct term based on the level of analysis, a recent review by Kuenzi and Schminke (2009) found that over 100 articles purported to measure organisational climate despite the unit of analysis being the individual, and therefore psychological climate being measured.

Some authors in the safety climate literature have similarly called for the differentiation of safety climate at the individual and group levels, with Neal and Griffin (2006) referring to individual level safety climate as “perceived safety climate” and Christian and colleagues defining it as “psychological safety climate” (Christian et al., 2009, p. 1104). However, such suggestions are yet to be entrenched among researchers, with new research being published regularly (e.g. Lu & Yang, 2011; Baek et al., 2008; Vinodkumar & Bhasi, 2009) which purport to measure safety climate when psychological/perceived safety climate is being measured. Such an arbitrary approach to labelling the construct among a number of researchers is extremely problematic for a variety of reasons. Firstly, it hinders the conceptual development of both constructs. Since safety climate is generally considered to consist of shared perceptions (Zohar, 2000, Oliver, Tomas, & Cheyne, 2006; Flin, 2007; Pousette et al., 2008), by conducting analyses at the individual level the unit of analysis is inconsistent with the unit of theory. Safety climate should be assessed at the group level in order to make conclusions about group-level processes, while perceived/psychological safety climate should be assessed at the individual level to draw conclusions about individuals.

In other words, differentiating between safety climate at the individual and the group level reduces conceptual ambiguity since it allows researchers to distinguish between individual and group level theory. By labelling a construct as “safety climate” yet assessing it at the individual level, a researcher promotes ambiguity, since there is the presumption that any pattern of relationships found are comparable to research which has aggregated data. Such an assumption has been found to be incorrect, with Kozlowski and Klein (2000) stating that relationships between constructs at the individual level may not hold at the group level. This was evident in a study by Ostroff and Rothausen (1997), where it was found that person-environment fit was affected by whether or not climate data was aggregated.

Perhaps most importantly, it has been found that safety climate perceptions tend to be shared within groups (Zohar, 2000; Oliver, Tomas, & Cheyne, 2006; Pousette et al., 2008), and therefore standard individual level analyses are not appropriate given that they assume independence of observations (Kreft & De Leeuw, 1998).

Operationalizing safety climate at the group level acknowledges this lack of independence. Studies which operationalize safety climate at the individual level may have inaccurate regression coefficients and standard error estimates (Twisk, 2006). This would be less problematic if safety climate assessed at the individual level was generally considered a separate construct, however as stated previously it is the effect these studies have in promoting ambiguity in the wider safety climate literature which is the cause for concern.

Though the dependency in observations suggests that individually operationalized safety climate should be eradicated as a construct, this is not necessarily the case. Psychological/perceived safety climate can still be operationalized at the individual level if multilevel corrections are performed which control for the shared experiences of individuals at the group level. For example, in the educational setting the test scores of children tend to lack independence due to the shared experience of having the same teacher, or by being in a school of a specific socio-economic status. Such dependency in observations does not prohibit the operationalization of test scores at the individual level; however it does necessitate controlling for variance at the class/school level in order to get the most accurate assessment of what predicts individual test scores. Similarly, as long as there is some conceptual model which explains that climate perceptions can exist at the individual level, controlling for variance at the group level may allow for a methodologically sound exploration of individual level perceptions. No study to date, however, has operationalized safety climate at the individual level and controlled for group level variance, with this failure to do so likely resulting in biased regression coefficients and standard error estimates.

In the current analysis, the effect that level-of-analysis and analytical technique has on research findings will be investigated, with the aim of determining the ramifications of not only operationalizing safety climate at the individual level, but operationalizing at the individual level and not taking into account the innate dependency of observations. While previous meta-analyses by Christian and colleagues (2009) and Beus and colleagues (2010) have compared the overall effect sizes of individual and aggregate operationalized safety climate, no study to date has investigated the effect of level-of-analysis on a single dataset. Hence, a number of analyses will be conducted in which multiple levels-of-analysis will be compared. Firstly, the assessment of criterion validity seen in Objective One will be reanalysed with both aggregated multilevel and individual level data. This will provide an insight into whether safety climate operationalized at the individual level displays a different pattern of results compared to the more methodologically and theoretically supported aggregate level analyses. Additionally, the standard methodologically unsophisticated individual level analyses will be compared with individual level analyses with multilevel corrections made for group level variance. This comparison will indicate how the acknowledgement of dependency affects regression coefficients and standard error estimates, therefore determining whether the results of studies which have assessed what could be labelled as psychological safety climate are possibly misleading.

Since these types of comparisons have not been undertaken previously in the safety climate literature, there are no firm predictions on what will be the likely results. For the comparison between aggregated multilevel and individual level safety climate, it is expected that the results will mirror the meta-analyses of Christian and colleagues (2009) and Beus and colleagues (2010), who found that individually operationalized safety climate demonstrated weaker associations with safety outcomes compared to aggregate safety climate.

Hypothesis 5a: Safety climate operationalized at the individual level will demonstrate weaker associations with safety outcomes compared to safety climate operationalized at the aggregate level.

Since safety climate operationalized at the aggregate level is a distinct construct compared to individual level safety climate, there may also be a different pattern of results. Kozlowski and Klein (2000) stated that relationships at the group level may not hold at the individual level, and this is the anticipated finding in the current analysis.

Hypothesis 5b: Safety climate operationalized at the individual level will demonstrate a distinct pattern of relationships with safety outcomes compared to safety climate operationalized at the aggregate level.

In the comparison between individual single level analyses and individual analyses with multilevel corrections, it is expected that the results will mirror that of Twisk (2006), who conducted similar comparisons in an epidemiological context. Twisk referred to the non-corrected individual analyses as “naïve” analyses in comparison to multilevel analyses, and so this more succinct terminology will be used hereafter. Twisk found that that when groups were balanced in terms of size, the difference between naïve and multilevel analyses was only in their standard error, with naïve analyses reporting lower standard error. When groups were unbalanced however, the regression coefficients and standard errors were much more divergent, and what were previously significant associations in the naïve analysis became non-significant when multilevel corrections were employed. Since the dataset is unbalanced in the current analysis (and in most organisational contexts), it is expected that the multilevel analyses will be far more conservative in terms of their regression coefficients and standard error, with results more likely to be non-significant.

Hypothesis 5c: Compared to the naïve analyses, the individual level multilevel analyses will produce more conservative results.

A further test of the effects of level of analysis and analytical technique will be in path analysis model comparisons. Path analysis, typically using a structural equation modelling approach, is common in the safety climate literature, with a number of authors conducting these analyses at the individual level (e.g. Neal, Griffin, & Hart, 2000; Rundmo, 2000; Huang, Ho, Smith, & Chen, 2006). As per the previous objective, a number of path models will be compared to determine the pattern of relationships between manager, supervisor, and co-worker commitment to safety and safety outcomes, with the difference being that all scales will be assessed at the individual level. The aim of this analysis is to determine whether the best fitting model at the individual level displays a different pattern of relationships compared to the best fitting model at the aggregate level. Given the frequency of research utilising path analysis at the individual level, this is an important avenue of research since it will further indicate whether safety climate assessed at the individual level is a distinct construct compared to safety climate at the aggregate level. This analysis is exploratory in nature, with no specific hypotheses about the manner in which the pattern of relationships will differ at the individual level compared to the aggregate level. However, it is expected that level-of-analysis will impact upon the observed pattern of relationships.

Hypothesis 5d: Compared to the best fitting aggregated multilevel path model, the best fitting individual level path model will display a different pattern of relationships between the safety climate scales and safety outcomes.

Overall, given the absence of research examining the impact of level-of-analysis and analytical technique in the safety climate literature, this analysis should provide much needed insight into the possible consequences of operationalizing safety climate incorrectly and using methodologically unsound analytical techniques.

9.2 Method

Please refer to Chapter Four for a full description of participants, measures, and procedure. In this chapter, data from Year One will be used.

9.3 Results

9.3.1 Cross-sectional Criterion Validity

As per Objective One, criterion validity was assessed with logistic regression using MLwiN v2.17 (Rasbash, Charlton, Browne, Healy, & Cameron, 2009). Data from Year 1 was used, which after the removal of groups with less than 3 members and cases with an illegible workgroup code, resulted in 749 individuals nested in 96 workgroups, nested in 11 facilities. The logit link function was utilised, with models first computed using first order MQL approximation, followed by second-order PQL approximation. For the aggregated multilevel analyses, safety climate scores were aggregated to the workgroup/facility level, with the intercept allowed to vary randomly. For the individual level multilevel analyses, intercepts were allowed to vary randomly and safety climate scores remained non-aggregated. For the naïve analyses, safety climate scores were at the individual level and intercepts remained fixed, in other words, no multilevel component was added. For all of the analyses, the safety outcome remained at the individual level. As per previous studies, the safety outcomes consisted of self-reported near misses, and self-reported injuries, which was a composite variable consisting of the sum of self-reported minor injuries and injuries. The presence of outliers was determined through inspection of standardised residuals and influence diagnostics. One outlier was removed at the group level. Individual level analyses were conducted after the removal of the outlier, since the aim of the analysis was to determine differences due to the analytical technique, with these differences potentially obscured by the presence of an outlier at a particular level. Since maximum likelihood estimation techniques were used, statistical significance was ascertained via the Wald test. The results of these analyses can be seen in Table 18.

Table 18

Comparisons between Naïve, Individual Multilevel, and Aggregated Multilevel Analyses using Data from Year One

	Naïve Near Miss	Individual Multilevel Near Miss	Aggregated Multilevel Near Miss	Naïve Injury	Individual Multilevel Injury	Aggregated Multilevel Injury
Co-worker Safety Climate	-0.476 (0.152)*	-0.440 (0.159)*	-0.613 (0.445)	-0.084 (0.130)	-0.095 (0.134)	0.315 (0.328)
Standards	-0.232 (0.138)	-0.200 (0.145)	-0.464 (0.389)	0.039 (0.119)	0.026 (0.122)	0.273 (0.295)
Communication	-0.453 (0.140)*	-0.409 (0.146)*	-0.681 (0.424)	-0.025 (0.123)	-0.027 (0.126)	0.155 (0.316)
Risk Management	-0.414 (0.137)*	-0.430 (0.165)*	-0.701 (0.409)	-0.111 (0.117)	-0.133 (0.120)	0.440 (0.299)
Involvement	-0.324 (0.112)*	-0.291 (0.117)*	-0.524 (0.345)	-0.117 (0.096)	-0.116 (0.099)	0.181 (0.275)
Supervisor Safety Climate	-0.323 (0.115)*	-0.289 (0.122)*	-0.785 (0.324)*	-0.115 (0.100)	-0.102 (0.103)	-0.280 (0.239)
Standards	-0.341 (0.108)*	-0.311 (0.115)*	-0.652 (0.291)*	-0.086 (0.094)	-0.077 (0.098)	-0.163 (0.216)
Communication	-0.290 (0.109)*	-0.242 (0.115)*	-0.988 (0.314)*	-0.117 (0.094)	-0.101(0.097)	-0.343 (0.232)
Risk Management	-0.283 (0.111)*	-0.267 (0.117)*	-0.755 (0.328)*	-0.077 (0.097)	-0.068 (0.099)	-0.204 (0.240)
Involvement	-0.194 (0.102)	-0.166 (0.107)	-0.535 (0.302)	-0.120 (0.088)	-0.106 (0.090)	-0.312 (0.227)
Manager Safety Climate	-0.217 (0.114)	-0.155 (0.114)	-1.342 (0.645)*	0.104 (0.101)	0.074 (0.101)	-0.138 (0.506)
Standards	-0.228 (0.111)*	-0.165 (0.111)	-1.267 (0.720)	0.122 (0.099)	0.090 (0.100)	0.004 (0.525)
Communication	-0.216 (0.101)*	-0.154 (0.101)	-1.100 (0.500)*	0.126 (0.091)	0.105 (0.091)	-0.211 (0.414)
Risk Management	-0.138 (0.111)	-0.083 (0.110)	-1.373 (0.795)	0.116 (0.099)	0.083 (0.099)	0.185 (0.553)
Involvement	-0.213 (0.102)*	-0.169 (0.102)	-1.272 (0.560)*	0.022 (0.090)	0.000 (0.090)	-0.286 (0.456)

As seen in Table 18, there were some similarities in findings between the three analysis types, such as the non-significant associations between safety climate and self-reported injury; however, there were some key differences. Aggregated multilevel analyses achieved higher regression coefficients compared to the individual analyses, with a paired samples t-test comparing the regression coefficients of individual multilevel and aggregated multilevel analyses reaching significance, t (14) = 3.58, $p < 0.05$. However, with the smaller sample size in aggregated analyses, the standard errors tended to be much larger, t (14) = -7.70, $p < 0.05$. Hence, while aggregated analyses demonstrated larger regression coefficients, and therefore would have a larger effect size, the confidence intervals of the effect size would also be larger. The smaller standard errors of the individual level analyses resulted in more safety climate subscales significantly predicting self-reported near misses, particularly when naïve analyses were performed. Hypothesis 5a was therefore not supported. However, the results were not clear-cut. The target of perceptions (co-worker, supervisor, manager) interacted with level of analysis to influence the strength of the relationship between safety climate and safety outcomes.

In the aggregate multilevel analyses, the co-worker scales demonstrated the weakest associations with near misses, while in the individual level analyses it demonstrated the strongest associations with near misses. If at the individual level the co-worker scale achieved significant yet weaker associations with near misses compared to individual level supervisor and manager safety climate, these findings could simply be explained by the increase in power at the individual level. However, the contrasting pattern of results at the individual and aggregate levels suggests that the dimensions that are important at the individual level differ to that at the aggregate level. This is further highlighted by the manager scale results, with aggregated analyses demonstrating significant associations with self-reported near misses and individual multilevel analyses failing to reach significance. Therefore, Hypothesis 5b was supported.

In the comparison between naïve analyses and multilevel analyses at the individual level, the multilevel analyses generally had lower regression coefficients, t (14) = -

7.19, $p < 0.05$, and higher standard errors, t (14), = -2.77, $p < 0.05$. The more conservative results for the multilevel analyses therefore support Hypothesis 5c. The inclusion of a random intercept slightly lowered the regression coefficients for the co-worker and supervisor scales, however for the manager scales the random intercept drastically lowered the regression coefficients, resulting in previously significant naïve associations becoming non-significant. This indicates that when facility level variance is taken into account, individual perceptions of management become considerably less important in predicting individual safety outcomes.

9.3.2 Path Model Comparisons

In the previous chapter it was demonstrated that supervisors were the primary influence on safety outcomes, with the model that included paths from supervisor safety climate and co-worker safety climate to safety outcomes achieving the best fit indices. Hence, the same path analysis comparisons will be performed to determine whether there is a different pattern of results at the individual level. Please refer to Chapter Eight (Figure 8 to Figure 12) for a description of the models compared.

Path analyses were performed using EQS 6.1. Mean scores were used for the co-worker, supervisor, and manager safety climate scales, with an injury frequency factor created which consisted of paths to self-reported near misses, minor injuries, and injuries. Self-reported injuries and minor injuries were freely estimated paths, while the self-reported near miss path was fixed at one to allow estimate of error variance. Data was skewed, particularly the dependent variable, with Mardia's normalised indicating a violation of multivariate kurtosis. This prompted the use of robust estimates which corrects for non-normality. Inspection of cases which contributed to multivariate kurtosis detected four outliers, which were removed. Multicollinearity and singularity was not evident as EQS was able to invert the matrices, with no convergence problems.

Firstly, Model 1 was compared to Model 2, and as per the group level results, Model 2 achieved superior fit indices (see Table 19). Model 1 still demonstrated good model fit, with the Yuan-Bentler residual-based and F statistic being non-significant, χ^2 (1) = 7.001, $p > 0.05$; F (6. 719) = 1.170, $p > 0.05$. Fit indices similarly demonstrated good model fit, with CFI = 0.999, NNFI = 0.998, RMSEA = 0.008 (0.000 to 0.050). Model 2 additionally achieved highly non-significant Yuan-Bentler residual based statistics, χ^2 (1) = 7.806, $p > 0.05$; F (7, 718) = 1.118, $p > 0.05$. Fit indices were marginally better than Model 1, with CFI = 1.000, NNFI = 1.001, RMSEA = 0.000, (0.000 to 0.045). Therefore, the more parsimonious model, in which is no direct path between manager safety climate and self-reported injury frequency demonstrated the better model fit.

Model 2 was then compared against Model 3, in which there is no direct path between manager and co-worker safety climates. As per the group-level analyses, the removal of this path resulted in the model achieving poor model fit, with both Yuan-Bentler residual-based statistics becoming significant, χ^2 (1) = 49.316, $p < 0.05$; F (8, 717) = 6.552, $p < 0.05$. Fit indices also suggested model misspecification, with CFI = 0.835, NNFI = 0.690, RMSEA = 0.116 (0.094 to 0.138). The results therefore mimicked the group level analyses, with managers having an important influence on co-workers, regardless of the level of analysis.

Model 3 was then compared with Model 4, in which the path between co-worker safety climate and self-reported injury frequency was removed. Unlike the group level analyses, Model 4 achieved slightly better fit indices. Model 4 similarly had highly significant Yuan-Bentler residual-based statistics, with χ^2 (1) = 49.606, $p < 0.05$, F (9, 716) = 5.852, $p < 0.05$, CFI = 0.843, NNFI = 0.738, RMSEA = 0.107 (0.086 to 0.128). Therefore, contrary to the previous criterion validity analyses, co-workers were not considered to be an important indicator of self-reported safety outcomes, with the more parsimonious model in Model 4 achieving better fit indices.

Finally, Model 3 was compared to Model 5, in which a full mediation model was tested. Both models demonstrated inadequate model fit, and achieved extremely similar fit indices. Model 5's Yuan-Bentler residual-based statistics were highly significant, with χ^2 (1) = 49.394, $p < 0.05$; F (8, 717) = 6.552, $p < 0.05$, with the CFI and RMSEA superior in Model 3, and the NNFI superior in Model 5, CFI = 0.826, NNFI = 0.711, RMSEA = 0.112 (0.092 to 0.133). This finding further suggests that the effect of different organisational levels of safety climate on self-reported safety outcomes could not be adequately estimated in the analysis, given the near identical results of the two-path models.

Table 19

Fit Indices for Individual Level Path Models

	Yuan-Bentler Residual-Based F Statistic	CFI	NNFI	RMSEA
Cut-Off Criteria		= / >.85	= / >.85	= / <.08
Model 1	1.170	0.999	0.998	0.008 (0.000 to 0.050)
Model 2	1.118	1.000	1.001	0.000 (0.000 to 0.045)
Model 3	6.552*	0.835	0.690	0.116 (0.094 to 0.138)
Model 4	5.852*	0.843	0.738	0.107 (0.086 to 0.128)
Model 5	6.552*	0.826	0.711	0.112 (0.092 to 0.133)

Hence, the hypothesis that the pattern of relationships at the individual level would be different to the pattern of relationships at the group level was not supported, with the second model achieving the best fit indices in both studies. Examination of parameter estimates (see Figure 17) showed that as per the group level analyses, there were strong and significant associations between manager safety climate and co-worker/supervisor safety climate. Similarly, supervisor safety climate was significantly associated with co-worker safety climate. However, the associations between the safety climate scales and self-reported safety outcomes were all non-significant. While co-worker safety climate demonstrated the strongest association with self-reported safety outcomes, no scale came close to reaching significance.

The lack of relationship between safety climate and self-reported safety outcomes explains the different findings compared to the previous chapter, as more parsimonious models with fewer paths to self-reported safety outcomes were rewarded in the current comparisons. Given that the majority of respondents did not experience a self-reported near miss or injury, it appears that the analyses were not able to pick up on the differences between individuals. This is reflected in the R^2 of 0.009 for the self-reported injury frequency factor, as compared to the R^2 of 0.25 in the previous chapter. While a path analysis based on a Poisson or binomial distribution would likely provide a different pattern of results, path analyses which test generalised linear models have not yet made it into mainstream statistical software. Therefore, though the overall pattern of results are the same at both levels of analysis, the relationships that the different safety climate scales have with self-reported safety outcomes may not be entirely accurate due to the nature of the data.

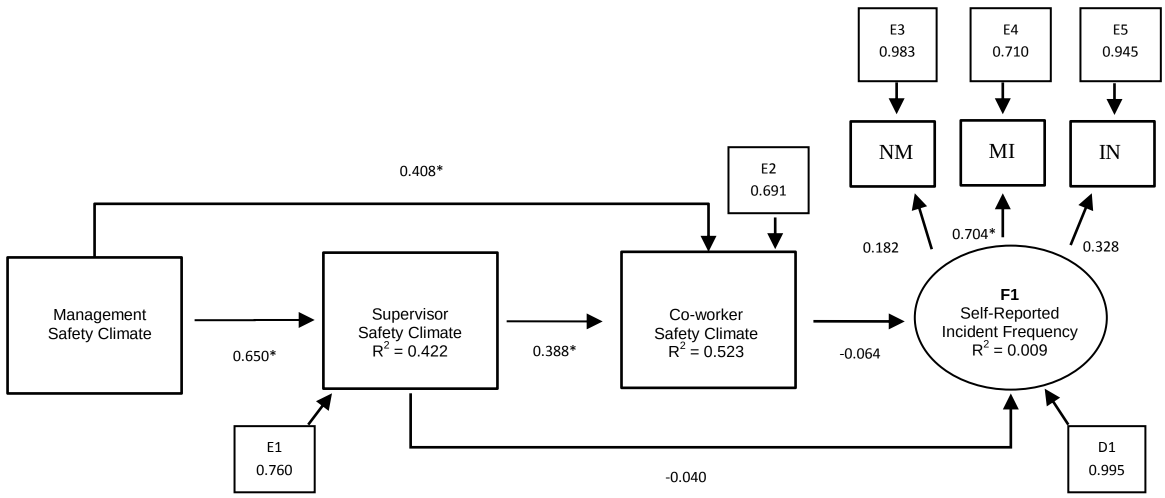

Figure 17. Parameter estimates for best fitting structural model (Model 2).

9.3.3 Cross-Validation Analyses

While there is confidence in the reported pattern of relationships between the different safety climate scales, the extremely low associations between safety climate and safety outcomes at the individual level require further cross-validation, particularly given that the findings contrast the previous cross-sectional criterion validity analyses. Hence, individual level analyses were performed using MlwiN v2.17 (Rasbash et al., 2009), with self-reported near misses as the dependent variable, and all three safety climates scales as independent variables. Like the path analyses, this analysis will determine which safety climate scales are significantly associated with self-reported safety outcomes, even after controlling for the effects of one another. As per the cross-sectional criterion validity analyses, logistic regression with a logit link function was utilised, with data from the first year. Models were first computed using first order MQL approximation, followed by second-order PQL approximation. Though corrections due to the non-independence of data were not possible in the path analyses, in these analyses random intercepts were added to the workgroup and facility level. The presence of outliers was ascertained by the inspection of standardised residuals and influence diagnostics, with one outlier removed at the facility level, and one outlier removed at the group level. Since maximum likelihood estimation techniques were used, statistical significance was ascertained via the Wald test. The results of these analyses supported the original cross-sectional criterion validity analyses as the co-worker scale was significantly associated with self-reported near misses, with a regression coefficient of -0.494 (0.238), χ^2 (1) = 4.307, $p < 0.05$. In contrast, the supervisor scale failed to reach significance, with a coefficient of -0.240 (0.181), χ^2 (1) = 1.758, $p > 0.05$. Similarly, the manager scale was not significantly associated with self-reported safety outcomes and had a mildly positive relationship, with a regression coefficient of 0.222 (0.192), χ^2 (1) = 1.338, $p > 0.05$. Therefore, the analyses suggest that the previous path analyses may not be correct in terms of the relationship that safety climate has with self-reported safety outcomes. While the path analyses suggested that none of the safety climate scales at the individual level were associated with safety outcomes, these results suggest that perceptions of co-workers are the strongest individual influence on safety outcomes – even after controlling for higher-level variance.

9.3.4 Exploratory Multilevel Mediation Analyses

The analyses in the thesis so far have found that perceptions of co-worker commitment to safety at the group level are not predictive of safety outcomes. This was clearly shown in the cross-sectional criterion validity analyses, the predictive validity analyses, and the path analysis comparisons. However, at the individual level, a different pattern of results emerge, with co-worker safety climate being a stronger indicator of safety outcomes compared to supervisor and manager safety climate. The significant association between co-worker safety climate and safety outcomes remained even after controlling for group and facility level variance, indicating that perceptions of co-workers at the individual level have a role in predicting safety outcomes that is separate from aggregated supervisor and manager safety climate. Given that this thesis has supported the notion that supervisor safety climate mediates the relationship between manager safety climate and safety outcomes, the strong predictive power of individual level co-worker safety climate suggests that it may mediate the relationship between supervisor safety climate and safety outcomes.

In order to test this tentative hypothesis, the Baron and Kenny (1986) 3-step method for testing mediation was used. Hence, supervisor safety climate should predict safety outcomes, supervisor safety climate should predict co-worker safety climate, and when co-worker safety climate is added to the supervisor safety climate → safety outcomes regression equation, the relationship between supervisor safety climate and safety outcomes should diminish or become non-existent.

These analyses were performed using MLwiN v2.2 (Rasbash et. al., 2009). In the analysis, supervisor safety climate was assessed at the group level, while co-worker safety climate and safety outcomes were assessed at the individual level. Safety outcomes were operationalized as self-reported near misses, assessed as a dichotomous variable (no near misses, one or more near misses). Hence, logistic regression was used in the associations between safety climate and safety outcomes, with a logit link function selected and random intercepts included.

Models were first estimated with 1st order MQL approximation, followed by 2nd order PQL approximation in order to achieve the most accurate estimates. Since the association between supervisor safety climate and co-worker safety climate does not involve dichotomous outcome variables, standard multilevel regression techniques were used. Given that normality is assumed in such analyses, a square root transformation with a reflection was carried out on both supervisor and co-worker safety climate to correct the slight negative skew. Standardised residuals and influence diagnostics were inspected to determine the presence of any extreme values, with one outlier being removed at the group level for the safety climate → safety outcomes analyses, and 6 outliers being removed at the group level for the supervisor safety climate → co-worker safety climate analysis. Significance was calculated via the Wald test, which employs a chi-square distribution with one degree of freedom.

The results supported a mediation process taking place. Firstly, supervisor safety climate predicted self-reported near misses, χ^2 (1) = 5.787, $p < 0.05$. Secondly, supervisor safety climate predicted individual level co-worker safety climate, χ^2 = 7.530, $p < 0.05$. Lastly, when both supervisor and co-worker safety climate were included in the prediction of self-reported near misses, supervisor safety climate fell slightly short of significance, χ^2 (1) = 3.161 , $p > 0.05$, while co-worker safety climate remained significant, χ^2 (1) = 5.664, $p < 0.05$. Hence, the relationship between group level supervisor safety climate and safety outcomes was mediated by individual level co-worker safety climate.

9.4 Discussion

This chapter uncovered a number of interesting and important findings, with the overarching finding being that safety climate at the individual level (i.e. perceived/psychological safety climate) displays a different pattern of results compared to aggregated safety climate. While there were similarities between individual and aggregate analyses in terms of the lack of relationship with self-reported injuries, the pattern of relationships each scale had with safety outcomes differed. Co-worker safety climate had the weakest relationship with safety outcomes when aggregated to the group level, though when it was analysed at the individual level it displayed the strongest relationship, even after controlling for group and facility level variance. The analyses further demonstrated the potential problems faced by researchers who operationalize safety climate at the individual level and who do not take into account the dependency of perceptions at higher levels. These analyses were the first to compare different analysis methods on the same dataset in the safety climate literature, and found that regression coefficients tended to be smaller and standard errors tended to be larger in individual level analyses which adequately accounted for higher level variance, compared to naïve analyses in which no such correction was made. Possibly the biggest contribution to the literature is the finding that the relationship between supervisor safety climate and safety outcomes is mediated by individual level co-worker safety climate. This indicates that in the prediction of individual safety outcomes, it is an employee's perception of the commitment to safety of those around them (i.e. a co-worker psychological/perceived safety climate) which is the most proximal. This finding therefore suggests an extension to Zohar's Multilevel Model of Safety Climate to include individual perceptions of co-workers, and additionally sheds light on the processes in which climate perceptions may affect behaviour and ultimately safety outcomes.

Researchers in the safety climate literature have commonly operationalized safety climate at the individual level with little regard to the possible consequences, both in terms of the effects on the analytical findings and on the conceptual development of the construct. While the arbitrary operationalization of safety climate clearly fosters ambiguity and impedes conceptual development, it was not known before this analysis how results may be affected by the level of analysis and analytical technique. Cross-sectional associations at the individual level found that perceptions of co-workers had stronger associations with self-reported near misses compared to supervisor or manager safety climate. These findings contrasted with group level analyses, where the opposite pattern of results emerged. Before this analysis, the only comparison between individual and aggregate level analyses was in the form of meta-analysis, with Christian and colleagues (2008) finding that individual level analyses tended to have weaker associations with safety outcomes. Though authors such as Zohar argued for the aggregation of safety climate data on conceptual and methodological grounds, there was little direct evidence to suggest that findings at the individual level were not generalizable to the wider safety climate literature. While the analyses upheld the findings of Christian, with regression coefficients weaker at the individual level, the dichotomy in findings based on level of aggregation suggests that level of analysis does affect the manner in which certain safety climate scales/subscales interact with safety outcomes. This therefore calls into question the generalizability of findings at the individual level. While co-worker commitment to safety is a relatively rare dimension in the safety climate literature, researchers that include the dimension (e.g. Seo et al., 2004; Turner et al., 2010) may find that their findings will not generalise when scores are aggregated to the group level. In addition, while supervisor safety climate at the group level will have a direct association with group level safety outcomes, at the individual level this relationship is mediation by co-worker safety climate. Therefore, the level of safety outcomes needs to be taken into account in addition to the level of safety climate when ascertaining the generalizability of findings.

This analysis was the first to operationalize climate at the individual level and control for higher level variance, with comparisons between naïve and corrected analyses producing compelling results. Compared to the standard 'naïve' analyses in which no correction is made, the individual multilevel analyses tended to be more conservative, with lower regression coefficients and higher standard error. Hence, the results reflect that of Twisk (2006) who achieved similar results in his comparisons in the epidemiological context. While the correction did not change the overall pattern of results for the co-worker and supervisor scales, the regression coefficients for the manager scale declined significantly. The standard error remained relatively unchanged, possibly because the small sample size at the facility level (N = 11) was insufficient for the detection of the relatively small differences in standard error as per the group level analyses. However, the correction to regression coefficients alone was enough for previously significant associations between subscales and self-reported near misses to become non-significant. Given that manager safety climate is the most commonly used dimension in the safety climate literature, this has concerning implications for research at the individual level which does not correct for the dependency in climate perceptions. The results suggest that research utilising naïve analyses (e.g. Seo et al., 2004; Turner et al., 2010; Vinodkumar & Bhasi, 2008; Wills, Watson, & Biggs, 2006) may be overestimating the relationship that safety climate has with safety outcomes. In the case of manager commitment to safety, the results suggest that once facility/organisational variance is accounted for, individual level perceptions of management commitment to safety become far less important in the prediction of safety outcomes. In other words, once differences between facilities are accounted for, differences between individuals in terms of their perception of manager safety climate become redundant. Additionally, in datasets where there is high within-group homogeneity and high between-group heterogeneity in climate perceptions, the effect of not accounting for the dependency in perceptions would be heightened. The intraclass correlation coefficients in the current analysis, particularly at the facility level, were relatively low, and therefore the potential for confounded results when corrective steps are not taken by the researcher is made clear by these findings.

The finding that the relationship between supervisor safety climate and individual outcomes is mediated by individual level co-worker safety climate is an important and unexpected result that sheds new light on the processes in which climate perceptions affect safety outcomes. Before this analysis, the dominant perspective was that individual employees reach a consensus on the priority of safety through their shared experiences and interactions with the supervisor (i.e. observing reward and punishment), and these perceptions inform desired behaviours, which in turn affect individual behaviour and the subsequent possibility of injury (see Zohar & Luria, 2005). The current analysis has demonstrated that there is an additional link between supervisor safety climate and individual safety outcomes. It appears that based on perceptions of commitment to safety at higher levels of the organisation, individuals develop their own perception of safety's priority among fellow frontline employees in their area, and it is these more proximal perceptions that most strongly predicts safety outcomes for that individual. In other words, employees synthesise higher level climate perceptions, which when combined with their own characteristics and experiences (i.e. individual variability), result in the formation of a perception of “the way things are done around here” among fellow frontline employees, which informs behaviour and therefore safety outcomes.

Though managers and supervisors are predictive of an individual’s co-worker safety climate, the significant associations with safety outcomes after controlling for group and facility level variance demonstrates that it is a distinctively individual level phenomena. Hence, while there are similarities between individuals when it comes to their perceptions of co-workers (as shown by the non-zero ICC’s), the results demonstrate that individual variability remains important in the prediction of safety outcomes and that a psychological/perceived safety climate construct can coexist with the more theoretically and empirically supported aggregated safety climate construct. This is an important finding, given that research generally describes safety climate as consisting of shared perceptions (Cooper & Phillips, 2004; Oliver et al., 2006; Zohar, 2000; Zohar & Luria, 2005), thereby requiring aggregation and multilevel analysis to avoid confounding results. While safety climate perceptions still need to be aggregated to the appropriate level, an individually operationalized psychological/perceived safety climate can be seen to exist as a distinct, important, and non-confounded predictor of safety outcomes, provided that adequate multilevel corrections are implemented.

The fact that co-worker perceptions were more important than supervisor and manager perceptions at the individual level makes it easier to differentiate among psychological/perceived safety climate and safety climate and therefore reduce the probability of future conceptual ambiguity. While perceptions of supervisor and manager commitment to safety remain the domain of safety climate and are always aggregated to their respective level, these individually relevant perceptions of co-workers can remain at the individual level in the assessment of psychological/perceived safety climate. This distinction can form the basis for the development of conceptual models which explain the role psychological/perceived safety climate has in the prediction of safety outcomes and its relationship with other variables such as safety climate.

Overall, the current analysis has uncovered a number of findings which should promote the conceptual development of safety climate. Firstly, it was demonstrated that individually operationalized safety climate displays a different pattern of results compared to aggregated safety climate, with perceptions of co-workers having a much stronger relationship with safety outcomes at the individual level. These analyses also demonstrated the potential inaccuracy of research findings which operationalize safety climate at the individual level without correcting for the dependency in observations, with non-corrected analyses underestimating standard error and overestimating regression coefficients. Lastly, it was found that the relationship between group-level supervisor safety climate and individual safety outcomes was mediated by individual level co-worker safety climate. These findings suggest an extension to Zohar's Multilevel Model of Safety Climate, offer further insight into the processes in which safety climate affects individuals, and provide a platform from which safety climate and psychological/perceived safety climate research can proceed in a conceptually and methodologically distinct manner

Chapter 10

General Discussion

10.1 Overview

In this thesis, the psychometric properties of a recently developed safety climate scale were investigated. In addition, a number of other analyses took place, all with the aim of shedding light on key areas of ambiguity in the safety climate literature. The implications of these findings will be discussed in the following sections. After a review of the major findings in each chapter, the theoretical implications will be discussed, with a focus on the role of co-workers, supervisors, and managers in promoting safety within organisations. The major methodological limitations will then be addressed. Next, directions for future research will be discussed, both in terms of the psychological/perceived safety climate literature, and the safety climate literature generally. Practical implications will then be discussed, followed by concluding comments.

10.2 Review of Aims and Major Findings

This thesis aimed to explore the relationships between safety climate perceptions at three levels of the organisation (manager, supervisor, co-worker), and the subsequent impact these separate levels of safety have on safety outcomes. The importance of co-workers in promoting safety was of particular interest, given the lack of multilevel studies examining the lagged effects of co-worker safety in the literature. By examining these lagged and cross-level effects, the aim was to replicate and extend upon Zohar’s Multilevel Model of Safety Climate. Finally, the thesis explored some of the methodological issues that may potentially impede progress in the safety climate literature. Safety climate has been operationalized at the individual and aggregate level, and so the aim was to examine the effect that level-of-analysis has on the pattern of relationships between safety climate and safety outcomes. In order to achieve these aims, a number of analyses were conducted to address the five research objectives.

Objective One was to assess the factorial validity of each scale in the safety climate survey. This was an important analysis, not only to ensure that the survey was psychometrically sound, but to determine whether safety climate was perceived to be a multidimensional or unidimensional construct. Though the survey was developed with a multidimensional framework in mind, authors such as Neal, Griffin, and Hart (2000) have operationalized safety climate as a unidimensional variable. Results of a confirmatory factor analysis indicated that employees perceived safety climate as a multidimensional construct at each level of the organisational hierarchy, a finding in line with the majority of research (e.g. Cooper & Phillips, 2004; Johnson, 2007; Seo, et al, 2004; Zohar, 1980; Zohar & Luria, 2005). Additionally, given the acceptable fit indices of the multidimensional model, each scale demonstrated factorial validity.

Objective Two was to investigate the criterion validity of the survey by performing cross-sectional associations between each safety climate scale and self-reported safety outcomes. The ability of a scale to achieve significant associations with safety outcomes is of particular importance given the overall role of a safety climate scale is to predict areas of the organisation that are at increased risk of injury. The multilevel analyses found that the scales assessing supervisor and manager commitment to safety were significantly associated with self-reported near misses, while the co-worker scale failed to achieve significant association with any of the safety outcomes. These results reflected the work of Zohar (2000; Zohar & Luria, 2005) and Johnson (2007), who operationalized safety climate using a similar multilevel behaviour-based approach and who previously demonstrated the central of role of management and supervisors in promoting safety within the organisation. The results indicated that individuals within workgroups with supervisors deemed to possess high commitment to safety experienced less self-reported near misses, and similarly, individuals within facilities with committed managers experienced less self-reported near misses. The non-significant co-worker results suggested that aggregated perceptions of co-workers had less of an impact in promoting safety compared to supervisors and managers, and suggested at this stage that Zohar's

Multilevel Model of Safety Climate need not be extended to include perceptions of co-workers.

Objective Three was to ascertain the predictive validity of each scale. Longitudinal studies are relatively rare in the safety climate literature, particularly those that aggregate safety climate scores to account for the dependency in perceptions. The benefit of longitudinal analyses over cross-sectional analyses is that it avoids the potential confound of employees providing low safety climate scores because they recently experienced a near miss/injury, and instead determines whether scores in the first year of data collection is associated with safety outcomes the subsequent year. The predictive validity analyses mirrored the cross-sectional analyses. Perceptions of supervisor commitment to safety at the group level predicted self-reported near misses at the group level. Aggregated perceptions of management commitment to safety had strong yet non-significant associations with safety outcomes, with medium to large effect sizes. These results were cross-validated when using official injury data, with manager safety climate similarly demonstrating non-significant yet medium to large effect sizes. Hence, the small sample size and non-parametric analyses were the likely cause of the conservative results. Co-worker commitment to safety once again failed to achieve significant associations with safety outcomes. The results supported the cross-sectional findings, indicating that the central role of supervisors in promoting safety was a robust effect, and demonstrated that Zohar’s Multilevel Model of Safety Climate could be generalised to the oil and gas industry.

Objective Four was to assess the cross-level effects of safety climate on safety outcomes through a series of path analyses. The aim was to determine whether the mediated relationship between manager safety climate and safety outcomes could be replicated in the oil and gas industry, and whether perceptions of co-workers separately mediated the relationship between supervisor safety climate and safety outcomes. Due to sample size restrictions, it was not possible to perform multilevel path analyses as originally intended, hence it was necessary to aggregate all three scales and safety outcomes to the group level to maximise sample size. Despite this setback, the path analyses supported the findings of Zohar and Luria, with the path model in which there was a direct path between supervisor safety climate and safety outcomes and an indirect path between manager safety climate and safety outcomes achieving the best fit indices. In addition, manager safety climate was seen to be strongly associated with supervisor and co-worker safety climate, reflecting Zohar's theory that management is the progenitor of safety climates at lower levels in the organisation. Validation analyses partially supported the path analysis findings, with the relationship between facility level manager safety climate and individual safety outcomes becoming non-significant when group-level supervisor safety climate was added to the regression equation. However, a non-significant association between manager safety climate and supervisor safety climate, possibly due to the inadequate sample size, prevented a mediation model being fully supported. Nevertheless, the results demonstrated the important and proximal influence of supervisors on safety outcomes.

Finally, Objective Five was to compare aggregate and individual level safety climate, given the ambiguity promoted by a lack of consistency in the literature when it comes to level of analysis. It was found that level-of-analysis had the potential to change the pattern of results, with co-worker safety climate demonstrating the strongest association with safety outcomes at the individual level. Additionally, when corrections were made for the dependency in climate perceptions at the individual level, previously significant associations became non-significant, a concerning result given the large number of studies which operationalize safety climate at the individual level and do not perform these corrections. The strong associations between individual level co-worker safety climate and safety outcomes, even after controlling for higher level variance, led to the testing of a mediation model with individual level co-worker safety climate mediating the relationship between group-level supervisor safety climate and individual level safety outcomes. The mediation model was supported, indicating that individual perceptions of co-workers were the most proximal indicator of safety outcomes. These results suggested that Zohar's Multilevel Model of Safety Climate could be extended to include individual perceptions of co-workers, however only when perceptions of co-workers were operationalized as an individual level variable.

Hence, this analysis providing further insight into the processes in which safety climate affects individual behaviour.

10.3 Theoretical Implications

There have been a number of safety climate models proposed (Christian et al., 2009; Flin, 2007; Griffin & Neal, 2000; Zohar & Luria, 2005), each with their own advantages and areas of focus. For example, while Griffin and Neal's focus was on the individual variables that shape behaviour, Zohar's model was focused on group and organisational variables that an organisation can target in their safety activities. In this thesis, the analyses and the interpretation of findings were framed according to Zohar's Multilevel Model of Safety Climate. According to Zohar's theory, employees form behaviour-outcome expectancies through their multilevel perceptions of the commitment to safety of supervisors and managers. Upon developing this theory, Zohar (2000; 2003; Zohar & Luria, 2005) operationalized safety climate in a manner different to other researchers and his original conceptualisation of the construct (Zohar, 1980). Most researchers other than Zohar assessed safety climate as a single-level construct, with disparate dimensions such as management commitment to safety, supervisor commitment to safety, safety communication, safety systems, and competence all assessed as separate subscales on a single scale (e.g. Williamson et al., 1997; Hoffman & Stetzer, 1998; Mearns, Flin, Gordon, & Fleming, 2001). This was the approach taken by Christian and colleagues and Griffin and Neal in their safety climate models, with Griffin and Neal focusing on manager commitment to safety in their scale. In comparison, Zohar operationalized safety climate as a multilevel construct, with dimensions assessing distinct behaviours loading onto separate supervisor or manager second order factors. Perceptions of supervisors were considered a group level construct, and therefore aggregated to the group level, while perceptions of management were considered a property of the organisation, and were therefore aggregated to the organisational level.

Despite these advantages of separating perceptions and aggregating to the appropriate level, very few researchers have followed Zohar's lead in abandoning the traditional method of safety climate scale construction. Johnson (2007) is the only author to have reused one of Zohar's scales, while Newman, Griffin, and Mason (2008) authored the only other non-Zohar authored article to have separated perceptions of supervisor and managers and examined cross-level effects, albeit with a very different itemisation. Given the absence of studies replicating Zohar's findings with a similar operationalization of the construct, the acceptable psychometric properties of the supervisor and manager scales in this thesis contribute to the literature by providing much needed support for Zohar's Multilevel Model of Safety Climate. With a similar multi-level structure and similar behavioural domains assessed, the factorial validity, criterion validity, and predictive validity demonstrated by the supervisor and manager scales suggests that Zohar's model generalises to other industries. This is a significant finding, given that Zohar's scales have only been tested in the manufacturing industry to date. There are likely substantial differences in the working environment between the manufacturing industry in Israel, where Zohar has tested his theory, and the oil and gas industry in Australia. Therefore the similar pattern of results in both environments suggests that Zohar's model is relatively robust and can be applied to the oil and gas context.

While the results overall supported Zohar's conceptualisation of safety climate, there are some specific areas where the results suggest some modifications or extensions could be made. Hence, in the following sections the implications of the results will be discussed in relation to the three levels of the organisation assessed.

10.3.1 Co-worker Safety Climate

It was originally hypothesised that co-workers would be a distinct source of behaviour-outcome expectancies at the group level. It was believed that in a similar manner to supervisor safety climate arising from the discretion that supervisors possess in their interpretation and implementation of management policy and procedure, a co-worker safety climate would arise from similar discretion among workgroups in their adherence to supervisory directives. Despite co-workers safety climate being included in a dimension in only a handful of safety climate studies (e.g. Lu & Tsai, 2008; Seo et al., 2004), such a hypothesis was justified given the number of studies which have demonstrated the important role co-workers have in promoting safety (e.g. Goldberg et al., 1991; Simard & Marchand, 1997; Turner et al., 2010)

Based on these findings it was believed that a group level co-worker safety climate dimension would be a proximal indicator of safety outcomes. In some groups behavioural norms may consist of warning other members of potential dangers, adhering to all higher level directives, and earnestly treating safety as the top priority, and these groups were hypothesised to have lower injury rates compared to groups with low safety priority norms, despite co-workers not having any formal powers to punish or reward behaviour. The saliency of co-worker perceptions in comparison to supervisors and managers were believed to stem from their immediacy, or as Turner and colleagues state “Since workers are relationally closer and more directly affected by the work practices of their coworkers, respondents may have been more likely to attend to cues from coworkers than from supervisors or senior managers about the importance of safety under demanding conditions” (p. 489).

Contrary to expectations, this did not turn out to be the case, with co-worker safety climate demonstrating consistently weaker associations with safety outcomes compared to supervisor and manager safety climate. In both cross-sectional and lagged analyses, the co-worker scale and its subscales failed to demonstrate significant associations with safety outcomes, with some associations being in the positive direction. In comparison, even when the supervisor scale did not reach significance in its associations with self-reported injuries, regression coefficients were still very much in the negative direction. In short, the results suggested the absence of a relationship between group-level co-worker safety climate and safety outcomes. While there was some uncertainty over whether perceptions of co-workers existed at the group or facility level, the level of aggregation did not change the pattern of results, with facility level co-worker safety climate similarly not significantly associated with safety outcomes.

The results did not suggest the absence of shared climate perceptions at the group or facility level. Intraclass correlation coefficients were of comparable size to the supervisor and manager scales, indicating that shared perceptions did exist at these levels. These shared perceptions, in the form of mean safety climate scores per group, were however not predictive of safety outcomes. Individuals within groups with a low average safety climate score were not more likely to experience self-reported near misses or injuries compared to groups with a high average safety climate score, a surprising result.

Given that the supervisor and manager scales all achieved significant associations with safety outcomes, reflecting past research (Zohar 2000; Zohar & Luria, 2005; Johnson, 2007), the poor co-worker scale results suggested that co-workers were not as salient of an influence on behaviour as previously thought. It suggested that supervisors, with their ability to punish and reward behaviour, were a much more salient source of behaviour-outcome expectancies. Hence, the results could be interpreted as suggesting that the prospect of losing one's job, or inversely praise or the possibility of promotion, were the key drivers of behaviour, rather than trying to follow any co-worker specific norms established by fellow employees. It was thought that the formalised, highly supervised environment of the oil and gas industry may have been another contributing factor to the lesser saliency of co-worker perceptions. Turner and colleagues (2010), who found that co-worker support was the most salient indicator in the railroad maintenance context, similarly suggested that the less formal presence of supervisors in their study may have contributed to their results differing to Zohar's.

However, when perceptions of co-workers were left unaggregated in order to gauge the effect of level-of-analysis, a more complex picture emerged. While co-workers demonstrated the weakest association with safety outcomes at the group level, when operationalized at the individual level it proved to be the strongest indicator of safety outcomes. Even after controlling for variance at the group and facility level the same pattern of relationships remained, with supervisor and management commitment to safety demonstrating non-significant associations when all three scales were added in the regression equations in the prediction of self-reported near misses. Hence, the results ended up mirroring that of Turner and colleagues. These results suggested that level-of-analysis had a substantial role in affecting safety climate results, with relationships at the aggregate level not holding at the individual level and vice versa.

A more surprising result emerged when a mediation model was tested, with the relationship between group-level supervisor commitment to safety and individual-level safety outcomes mediated by individual-level co-worker commitment to safety. In line with the individual level analyses, this mediation model was supported, with group level perceptions of supervisor commitment to safety becoming non-significant when individual level co-worker commitment to safety was included in the regression equation. This indicated that while supervisor commitment to safety directly predicted group level safety outcomes, in the prediction of individual level safety outcomes, individual perceptions of co-worker commitment were the most proximal predictor. These results therefore suggest that Turner and colleagues and Zohar's results are not contradictory at all, but rather demonstrate that the level of analysis of the safety outcome does determine what level of the organisation is the most proximal. This is a key finding, and if replicated in future studies, may reduce ambiguity in the literature given it explains contradictory findings such as the one mentioned previously, and suggests that analyses with an individual level safety outcome are only comparable to other studies which have similarly assessed safety outcomes at the individual level, with the same applying to aggregated outcomes.

Zohar's Multilevel Model of Safety Climate positioned supervisors as the most proximal influence on employee behaviour due to their ability to form behaviour-outcome expectancies among frontline employees through reward/punishment. The results suggest an additional link between supervisor commitment to safety and individual safety outcomes. It appears that employees develop multilevel perceptions of commitment to safety from observing supervisors and managers as per Zohar's theory, but instead of these perceptions directly informing behaviour, these multilevel perceptions contribute to an employee's own perception of safety's priority among fellow frontline employees. This individual perception of safety's priority among co-workers becomes the strongest indicator of an employee's propensity to get injured.

There are some potential reasons why this relationship exists at the individual level and not at the aggregate level. While the non-zero intraclass correlation coefficients (ICC) demonstrate that there are similarities among employees in their perception of co-workers, the strong associations with safety outcomes after controlling for group and facility variance indicates that it is a distinctively individual level phenomena. The significant associations between manager/supervisor safety climate and individual level co-worker safety climate suggests that employees synthesise climate perceptions from multiple levels of the organisation, which when combined with their own characteristics and experiences (i.e. individual variability), form a perception of "the way we do things around here" among fellow frontline employees. These subjective perceptions of co-workers then inform behaviour and therefore safety outcomes. Given that psychological climate is suggested to arise from the interaction of quasi-facts and intersubjectivity (Field & Abelson, 1982), and is affected by worldviews, perceptual biases, and previous experience (Ostroff & Bowen, 2000), it can be seen how employee subjectivity in conceptualising how safe similarly ranked employees behave can result in individual level perceptions being more predictive of individual safety outcomes compared to mean group scores. In comparison, perceptions of supervisors and managers may be based in a more objective reality (Hardin & Higgin, 1995; Zohar, 2003), whereby social interaction validates and promotes a perceptual consensus of these more distant figures, resulting in shared perceptions having a stronger relationship with aggregated safety outcomes.

Another possible reason for individual perceptions of co-workers demonstrating a stronger relationship with safety outcomes compared to supervisor/manager commitment to safety is that co-worker perceptions may serve as a proxy for an employee's own behaviour. At the beginning of the research project it was suggested that one potential benefit of assessing perceptions of co-workers is that it may provide a less biased insight into the behaviour of the employee compared to a scale that asks the individual to rate their own commitment to safety. It is widely known that when individuals report on their own behaviour, there is a tendency to over-report desired behaviours and underreport undesired behaviour, in other words, a social desirability bias (Donaldson & Grant-Vallone, 2002; Moorman & Podsakoff, 1992). In the organisational setting, this social desirability bias may be more acute, due to fear of employers taking action against them due to their responses, even if the possibility is remote (Donaldson & Grant-Vallone, 2002). Therefore, by measuring perceptions of co-workers, an unguarded insight into the behaviour norms present among frontline employees may be achieved. If the behaviours of co-workers did in fact reflect an individual's own behaviour, this would explain why individual perceptions of co-workers were the most proximal predictor of individual safety outcomes.

While the mechanisms in which individual level co-worker perceptions affect behaviour are not clearly understood, this mediating variable may resolve the dichotomy of findings in the safety climate literature. While authors such as Zohar (2000) and Johnson (2007) have found that safety climate directly predicts safety outcomes, many other authors believe this relationship is mediated by individual variables such as safety motivation/knowledge (Neal & Griffin, 2006; Flin, 2007; Christian et al., 2009). Previously, the dichotomy in findings could be explained by the different operationalization of the construct by the two groups of authors. While Zohar and Johnson used scales with which assessed perceptions of specific behaviours, authors such as Neal and Griffin assessed safety climate though perceptions of a non-specified commitment to safety, with no behaviours listed. This less specific interpretation of safety climate was then seen to indirectly predict self-reported safety compliance and participation, which in turn predicted accidents at the aggregate level. Two subscales in Zohar's scale assessed safety compliance and participation behaviours, potentially explaining the more proximal predictive power of safety climate in his studies.

However, in the current study a behaviour-based operationalization of safety climate was utilised with strong similarities to Zohar's scales, and yet an individual level variable was seen to mediate the relationship between supervisor safety climate and safety outcomes. Hence, the current study supports an individual level mediation process taking place as espoused by models of Flin (2007) and Neal and Griffin (2006). While in the previously mentioned models the mediating variable was safety motivation, in the current study it was psychological/perceived safety climate, assessed through the perceptions of co-worker commitment to safety. Both variables may be similar conceptually, with Flin regarding motivation as relating to expectations regarding the outcome of behaviours, and Neal and Griffin defining it as the willingness of an employee to act safely and the valence associated with these behaviours. Individual level perceptions of co-workers would also relate to behaviour-outcome expectancies and the willingness to act safely, with perceptions of how safe employees in a similar position behave (and the ramifications of behaviour) likely acting as a motivational driver on the individual, as seen through their direct and proximal prediction of safety outcomes. In other words, these subjective perceptions of co-workers, which reflect "the way we do things around here", may motivate and direct behaviour as per the mediating variable in Flin/Neal and Griffin's model.

Overall, these findings suggest that Zohar's Multilevel Model of Safety Climate could be extended to include individual perceptions of co-workers, in order to more comprehensively describe the cross-level processes in which safety climate affects individuals. Though it is uncertain exactly why individual level perceptions of co-workers predict safety outcomes and group level perceptions do not, the results suggest that at the individual level, co-worker commitment to safety is more proximal than supervisor and management commitment to safety. Even after controlling for group and facility level variance, the results suggest that co-worker commitment to safety is the most proximal predictor of safety outcomes. In this sample, individual level co-worker safety climate is a distinct predictor of safety outcomes; however it is unknown whether it achieves this by providing an insight into an individual's own commitment to safety, or by simply being the outcome of an employee's multilevel perceptions of the workplace coupled with their individual characteristics and experiences.

10.3.2 Supervisor Safety Climate

The scale assessing supervisor commitment to safety was the most consistently performing scale of the survey. It demonstrated acceptable factorial validity, and suggested criterion and predictive validity through its associations with self-reported near-misses, a feat not achieved by the co-worker or manager scales. Such findings are reflective of Zohar's Multilevel Model of Safety Climate, which championed the role of supervisors as a key influence of behaviour, in comparison to other researchers who concentrate solely on management (e.g. Neal & Griffin, 2006). According to Zohar's model, the policies, procedures, and practices stemming from management do not cover every eventuality, and so supervisory discretion results in a group level supervisor safety climate being formed. This climate is a more proximal predictor of safety outcomes since supervisors provide punishment/reward more frequently and immediately than managers. This aspect of Zohar's theory was partially supported by the findings. The path analyses demonstrated that the model with supervisor and manager safety climate predicting safety outcomes had poorer fit indices than the model with supervisor safety climate alone predicting safety outcomes, however, since manager safety climate was assessed at the group level it is unknown how this may have affected the pattern of relationships. It is possible that this mediation finding would not hold if manager safety climate was aggregated to the facility level where it belongs. Multilevel mediation analyses were similarly obtuse. The association between manager safety climate and safety outcomes became non-significant when supervisor safety climate was added to the regression equation; supporting a mediated relationship, however it could not be determined whether manager safety climate predicted supervisor safety climate. In both cases, inadequate sample size was the cause of these ambiguous findings. Since in both analyses the results were generally supportive of a mediation process occurring, reflecting the findings of Zohar and Luria, the weight of the evidence is in favour of this process taking place and supervisors being a more proximal influence on group level safety outcomes as compared to management.

The best performing subscale was the communication subscale, which shares similarities with Zohar and Luria's declarative practices subscale. In the declarative practices subscale the focus is more on declared, publically espoused messages to employees, while in the communication subscale a two-way approach to communication is depicted. Items in the communication subscale relate to supervisors listening and acting upon safety concerns raised by employees, rather than just declarative behaviours. Items additionally relate to recognising good behaviour and punishing poor safety performance, and so the strong associations with safety outcomes are not surprising. As previously stated, supervisors play an important role due to their ability to reinforce/punish behaviour, resulting in the formation of behaviour-outcome expectancies and demonstrating the priority of safety. While the items relating to punishing/rewarding behaviour are obvious in their links to Zohar's theory, the items which assess listening behaviours also relate to the reinforcement of behaviour. As Zohar and Luria and other researchers have stated (e.g. Luthens, 2000), simple attention and recognition are powerful reinforcers. Having a supervisor who not only earnestly listens to safety concerns and ideas, but acts upon them, likely operates as a significant reinforcer for employees. This reinforcement would demonstrate to employees in the group the priority that safety holds, and increase the likelihood of similar safety orientated behaviour occurring in the future. Hence, while the other subscales are undoubtedly important, and list behaviours which demonstrate the overall priority of safety, the superior predictive and criterion validity of the communication subscale stems from the fact that it taps into the core meaning of safety climate more closely.

The predictive power of this reinforcement based subscale is also explainable by other related organisational theories. For example, in expectancy-valence theory, employees engage in particular behaviours due to an expectation of attaining some sort of desired outcome from that behaviour (Vroom, 1964). Hence, in an analogous manner to behaviour-outcome expectancies, if an employee perceives that acting safely or suggesting safety improvements will result in reinforcement from their supervisor, they will be more motivated to engage in this behaviour (Neal & Griffin, 2006). Similarly, if other employees perceive this reinforcement occurring, according to social learning theory this will affect the frequency in which they themselves engage in the behaviour (Sims & Manz, 1982).

10.3.3 Manager Safety Climate

As previously stated, manager safety climate appeared to be an indirect predictor of safety outcomes, providing support for Zohar's Multilevel Model of Safety Climate. This is an important finding, not only because it demonstrated that Zohar's theory was generalizable to the oil and gas industry, but because mid-level management was being assessed rather than top management. In Zohar's studies, manager safety climate was aggregated to the organisational level, with items directed at top management. In contrast manager safety climate in the current study was aggregated to the facility level, with items directed towards facility-level management, i.e. middle management. The possibility of such intermediary levels of safety climate was discussed by Zohar and Luria, who suggested that when top management define policies, management levels below re-interpret them to reflect their own priorities, with this process cascading down the organisation. Zohar and Luria therefore proposed that supervisors use mid-level management as a referent for their perceptions and expectations. They suggested that this could be investigated by assessing perceptions of frontline employees, since it is likely they are aware of mid-level management priorities, or through the perceptions of supervisors themselves. The former was tested in the current study, and so the general support for Zohar's mediation findings suggest that this multilevel cascade model does extend to mid-level management and frontline employees are aware of their priorities.

While the path analyses showing manager safety climate predicting lower levels of climate are to be treated with some caution due to level of analysis issues, the results are overall supportive of previous research which has positioned management as a key figure in the establishment of climate and culture throughout an organisation (Hofstede et al., 1993; Flin, Mearns, O'Connor, & Bryden, 2000; Zohar & Luria, 2005; Zohar, 2003; Arboleda, Morrow, Crum, & Shelley, 2003). Therefore, while manager commitment to safety appears not to be a direct predictor of safety outcomes, its position as safety climate's most commonly assessed dimension is not under threat by the study findings. However, the findings do highlight the importance of separating perceptions of different organisational levels in safety climate scales. Studies which include manager commitment to safety and supervisor commitment to safety in a singular scale may result in an underestimation of the association with safety outcomes.

10.4 Limitations of Study

While every possible step was undertaken to ensure that analyses were undertaken in a methodologically rigorous manner, some limitations are present, potentially affecting the generalizability and robustness of the research findings.

10.4.1 Sample Size and Characteristics

The most significant problem encountered in the study was the relatively small sample size at the aggregate level. Though there were a large number of individual respondents, the manner in which workgroups were organised meant that some had in excess of 30 employees and others were much smaller. Given that there needed to be at least three employees in a group for it to be included in aggregated analyses, a number of groups had to be removed since less than three members replied/had useable data. This was exacerbated in the longitudinal analyses, given that it was necessary to have groups with sufficient members over consecutive years. The lower than expected sample size was particularly evident when attempting to do individual data matching so that true longitudinal analyses could be attempted. Less than 40 employees completed the optional data matching item and had useable data in both years, which prevented these analyses from being conducted and suggested that employees were concerned about identification.

Given the apparent concern over identification, there is the possibility that respondents may have provided inaccurate data, with less safety minded or previously injured personnel potentially less likely to complete the survey. The anonymous nature of the survey was clearly stated on the participant information sheet, and so it is possible that uncontrollable organisational events may have contributed to this phenomenon. While the number of respondents who completed the personnel code item was very low, overall response rate was quite high (Year 1 = 66%, Year 2 = 59%), with the vast majority of workgroups represented. Hence, it is hoped that that the data reflects the experience of individuals employed in the organisation, however further replication is required.

While sample size at the group level was not optimal, there appeared to be sufficient power for the group level analyses. For the path model comparisons, Bentler (2006) states that as long as EQS can reject certain models (i.e. differentiate between poor and well-fitting models), the sample size is likely sufficient. For the tests of criterion and predictive validity, the supervisor scale significantly predicted self-reported near misses while the co-worker scale did not, reflecting past research findings and demonstrating the ability of the dataset to differentiate between a poor and good predictor of safety outcomes.

Given that data was collected from a single organisation, the small sample size at the facility level was a more serious dilemma that prevented certain analyses from being performed. While it was originally envisioned for the path analyses to be performed using multilevel techniques, with only nine facilities sampled over subsequent years, this vision turned out to be unrealistic. Since manager safety climate had to be aggregated to the group level instead of the facility level, the pattern of relationships may not hold when the manager scale is correctly aggregated. While the path analyses largely reflected Zohar’s research in which the scale was correctly aggregated, the strong associations with co-worker safety climate is potentially a misleading result. Since no previous research has examined the cross-level relationships with co-worker safety climate, it is difficult to make any firm conclusions and points for the need for future research to replicate the results in a more methodologically sound manner.

The low facility sample size also may have prevented the predictive validity analyses of the manager scale reaching significance, with a conservative Spearman's rho analysis needing to be used due to uncertainty over the distribution of the data. Lastly, the multilevel mediation analyses may also have been confounded by the low facility sample size. MlwiN was unable to detect any facility level variance, which likely contributed to the manager scale failing to predict the supervisor scale so as to support a mediation model taking place. Twisk (2006) states that the inability of the program to detect variance may be due to it being unimportant, and there is always the possibility that group level variance is much more important than facility level variance in the prediction of supervisor safety climate. However, given the extremely small sample size, it is more likely that facility level variance could simply not be calculated. Therefore, while the inability of the manager scale to predict supervisor safety climate led to a mediation model not being supported, there is a possibility that with a larger sample size the mediation model would have been supported, reflecting the findings of Zohar and Luria (2005).

The suboptimal sample size at the aggregate level is not a unique limitation of the current study. For example, Cooper and Phillips (2004) had a sample size of six, Johnson (2007) had 17, Neal and Griffin had 33, and Mearns, Whitaker, and Flin (2001) had nine. Getting a large number of organisations to agree to administer the same safety climate survey over a number of years is a gargantuan task, and possibly explains the lack of multilevel path analyses in the literature. One positive outcome of the current study is that analyses at the facility level assessing mid-level management appear to be analogous to organisational level analyses assessing upper management, in terms of the relationship with supervisor safety climate and safety outcomes. Hence, even if a researcher has access to only one large organisation, being able to examine cross-level effects that include manager commitment to safety is still possible. Overall, while the small sample size is a definite limitation, it is a limitation shared by most research in the literature where an attempt is made to aggregate data in order to perform more methodologically rigorous analyses.

10.4.2 Quality of Outcome Variables

Another serious limitation of the study was the quality of the outcome variables, which consisted of self-reported injury data. Self-reported data was used in the current study since the organisation did not collect group level injury data, and individual injury data was not sought since the survey was designed to protect employee anonymity. The primary problem with self-report data for both predictor and criterion variables is that common method variance may explain the pattern of relationships between variables (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Podsakoff & Organ, 1986). Employees may form illusory correlations between the two self-report measures, where they possess assumptions concerning the co-occurrence of items resulting in the systematic distortion of correlations (Berman & Kenny, 1976). Social desirability and negative affectivity can also alter how participants respond, masking true relationships (Podsakoff et al., 2003). The fact that there were significant associations with self-reported near misses, which have subjective perceptual characteristics, may therefore be a product of common method biases rather than an actual relationship.

Self-reported data is relatively common in the safety climate literature, with a meta-analysis by Christian and colleagues (2009) finding that 92% of studies used self-reported data when safety climate was operationalized at the individual level, and 32% used self-reported data when safety climate was aggregated to the group level. Christian and colleagues also found that it did not lead to inflated associations; instead they cautiously suggested that self-reported data has a tendency to suppress the relationships between variables. In a recent review, Spector (2006) suggests that the threat of common method variance has been distorted and exaggerated over time, becoming a methodological ‘urban legend’. While Spector notes that biases do exist in research, he states that there is little evidence of variables such as social desirability or negative affectivity influencing associations. Spector referred to the comprehensive review of Cramptom and Wagner (1994), who compared the strength of correlations in 581 articles. They found that studies which utilise one source of data (e.g. self-reported surveys) were not significantly different in terms of correlation strength compared to studies which utilised multiple sources of data in the majority (62.2%) of cases. Overall, Spector argues that common method variance is not a universal inflator of correlations, but appears to only affect a small number of variables and only some of the time. My own analyses found no evidence of an inflationary effect when comparing self-reported to official organisational injury data. The associations between manager safety climate and official injury data was stronger than manager safety climate and self-reported injury data, suggesting an attenuating effect of self-reported data if anything. Therefore, due to the weight of previous research findings, coupled with my own findings, the threat of common method variance, while it cannot be completely dismissed, is minimal.

10.4.3 Possible Confounding Variables

There are a number of variables that were not measured which may have affected the pattern of relationships between safety climate and safety outcomes. As previously stated, negative affectivity and social desirability can distort correlations, prompting Neal and Griffin (2006) to control for negative affectivity in their analyses. However, Neal and Griffin stated that by controlling for negative affectivity, there was the possibility that true relationships may have been masked since negativity affectivity may be a source of stability in climate perceptions and behaviour over time.

A potentially more important variable not controlled for in the current study was risk. In a large organisation such as the one studied, there would be some employees involved in risky work (e.g. maintenance in offshore platforms) and some employees in relatively risk free work (e.g. office based personnel). It is unknown how the different exposure to risk may have masked or attenuated the results. Some exploratory analyses were conducted to determine if removing employees from office roles would strengthen associations, and this was not the case. This may be because a number of office based employees make regular visits to worksites offshore. Even in the same workgroup, employees may experience different exposure to risks due to different conditions (Zohar, 2000), and so an individual item measuring the perception of risk may have provided a clearer picture on the relationship safety climate has with safety outcomes. The lack of assessment of risk may not have confounded results however. Zohar (2000) assessed level of risk in his study and found it did not predict injury, suggesting that unsafe behaviour was far more important than unsafe conditions in the prediction of injury.

While measuring these additional variables may have provided more defensible conclusions, the downside of including additional scales is that it places a higher burden on the employee. While Neal and Griffin's (2006) scales were only a few items in length, the safety climate survey used in the current study had in excess of 50 items, and included additional open-ended questions. Research has shown that as survey length increases, respondents are less likely to finish the survey, and spend less time on the questions and provide more uniform answers to questions later in the survey (Galesic & Bosnjak, 2009). Hence, while there may have been advantages for including additional items, there is the possibility of an overall reduction in the quality of data collected.

10.5 Future Directions for Research

10.5.1 Future Directions for Perceived/Psychological Safety Climate

Before I outline possible future directions for the perceived/psychological safety climate literature, it must be noted that these conclusion are based on findings from one organisation, using one instrument, and in one context. In addition, significant associations were only found between safety climate and self-reported near misses, with no significant association demonstrated with self-reported injuries. Hence, there is a need for these findings to be replicated before any firm conclusions can be made. However, despite these obvious limitations, in the forthcoming section I will describe the manner I believe the construct of perceived/psychological safety climate can progress conceptually and empirically, based on the current research findings.

As the results of individual and aggregate level safety climate comparisons suggest, safety climate assessed at the individual level is a distinct construct to safety climate assessed at the aggregate level, reflecting the research of Kuenzi and Schmidt (2009). Since patterns of results at the individual level do not appear to hold at the aggregate level, the findings of authors who operationalize at the individual level are likely not generalizable to findings at the aggregate level. The findings therefore suggest that researchers and journal editors need to be vigilant in how safety climate is named and operationalized, so as to promote the conceptual development of the constructs and to avoid the ambiguity that plagued the organisational climate literature.

Research and theory such as Zohar's Multilevel Model of Safety Climate support the notion that safety climate exists solely at the aggregate level. This is because perceptions of safety climate tend to be shared among workgroups/organisations; with individuals having similar perceptions of the priority safety is afforded by supervisors/managers (Oliver, Tomas, & Cheyne, 2006; Pousette, Larsson, Torner, 2008). The shared nature of climate perceptions therefore make traditional individual level analytical techniques flawed since they violate the assumption of independence of observations (Kreft & De Leeuw, 1998). Though such methodological and theoretical arguments suggest that safety climate research at the individual level should be discontinued, this is not necessarily the case. In order for individually operationalized safety climate research to continue and prosper, it is proposed that two criteria need to be met.

1. It needs to be placed within a conceptual model distinct from aggregate safety climate theory which clearly outlines what it is (e.g. definition, dimensionality), what causes it, and how it affects other variables of interest.

2. Despite it being an individual level variable, multi-level corrections should be utilised to ensure that group/organisational homogeneity in perceptions does not confound results.

The first aspect of promoting the development of a coherent individual level safety climate research is in the choice of its name. A number of names have been mentioned in the literature to date, for example psychological safety climate (Christian et al., 2009), which borrows its name from a similar distinction between individual and aggregate perceptions in the organisational climate literature, and perceived safety climate (Neal & Griffin, 2006). For the sake of parsimony and the reduction of ambiguity, it is best for researchers to stick with one name. Though the term psychological safety climate makes a lot of intuitive sense due to its previously mentioned links to the organisational climate literature from which safety climate was derived from, there is one foreseeable disadvantage. Another facet specific climate emerging from the organisational climate literature has been psychosocial safety climate, which refers to an organisation's commitment to promoting the psychological wellbeing of its employees (Law, Dollard, Tuckey, & Dormann, 2011). Though its definition alone is enough to promote confusion with psychological safety climate, some authors in the psychosocial safety climate literature interchangeably use the term psychological safety climate to describe the construct (e.g. Bradley, Postlethwaite, Klotz, Hamdani, & Brown, 2012). Given climate's rich history of ambiguity and the misnaming of constructs, the use of the term psychological safety climate is potentially ambiguous. There is no such similar potential for confusion with the term perceived safety climate, with no similar named terms and a name which clearly refers to safety climate, rather than another of the facet specific climates.

Secondly, there needs to be a generally agreed upon definition of the construct. For safety climate, it is generally agreed that it consists of shared perceptions of commitment/priority of safety in the workplace (Cooper & Phillips, 2004; Johnson, 2007; Huang et al., 2007; Neitzel et al., 2008; Newman et al., 2008; Vinodkumar & Bhasi, 2009). Since perceived safety climate is a distinct construct from safety climate, its definition needs to differentiate itself from safety climate in order to reduce ambiguity. Neal and Griffin (pp. 946-947) defined perceived safety climate as "individual perceptions of policies, procedures, and practices relating to safety in the workplace". Christian and colleagues, drawing on the work of a number of other authors (James & James, 1989; James, Hater, Gent, & Bruni, 1978; James & Sells, 1981) defined perceived safety climate as "individual perceptions of safety-related policies, practices, and procedures pertaining to safety matters that affect personal well-being at work” (p. 1106). Such definitions are a good starting place in describing the construct, given that they point to perceptions of policies, practices and procedures, allowing links to Zohar’s Multilevel Model of Safety Climate, where safety’s priority is ascertained through perceptions of enacted policies, practices, and procedures (Zohar & Luria, 2005). The definitions also clearly state that it consists of individual perceptions, clearly delineating it from safety climate which consists of shared perceptions that exist at an aggregate level. Christian and colleagues then go on to state that perceived safety climate is driven by an emotional evaluation of the work environment; however such a conceptualisation of the construct may promote ambiguity, given that emotion and evaluation are considered aspects of attitudes (Jones & James, 1979). In comparison, climate is generally of a descriptive and cognitive nature, regardless of whether organisational climate or safety climate is the construct of interest (James & Jones; Zohar & Luria, 2004). Hence, the descriptive and cognitive nature of perceived safety climate should be stressed in any conceptualisation of the construct. Guldenmund (2000) notes that recent conceptualisations of attitudes emphasise a cognitive component, however to reduce ambiguity, perceived safety climate should be operationalized solely through perceptions. While perceived safety climate perceptions may be subjective and biased (Ostroff & Bowen, 2000), focusing on perceptions rather than attitudes has a number of advantages. Firstly, it’s conceptually congruent with the safety climate literature, with most authors specifying the perceptual nature of safety climate (e.g. Zohar, 1980; Brown & Holmes, 1986; Glennon, 1982; Niskanen, 1994; Neal & Griffin, 2006; Oliver, Tomas, & Cheyne, 2006; Hahn & Murphy, 2008). Secondly, it prevents a definitional ‘creep’ occurring. A non-specific conceptualisation of the construct may result in perceived safety climate encountering similar problems to organisational climate, where there was confusion over the differences with organisational culture and the conceptual boundaries of the construct. Lastly, research has progressively supported the distinctiveness of attitudes and safety climate (Beus et al., 2010; Pousette et al., 2008), and so there is little conceptual or empirical support for the addition of attitudes in any conceptualisation of perceived safety climate.

What may also promote the conceptual development of safety climate is if its definition specifies what the targets of perceptions are. Perceived safety climate should not simply be a non-aggregated form of safety climate, given that the target of perceptions, and therefore the dimensionality of the scales, differs between the levels of analysis. While the perceptions can relate to enacted policies, procedures and practices, in safety climate the target of these perceptions are either supervisors or managers, with data aggregated to reflect the innate dependency of perceptions directed towards these levels of the organisation. In a scale assessing perceived safety climate, I suggest that it is not necessary to assess supervisor or management commitment to safety, not only because the perceptions exist at an aggregate level, but because perceptions of co-workers appear to be a far more proximal predictor of safety outcomes at the individual level. Hence, if a perceived safety climate definition specified that co-workers are the target of perceptions, then this would be far more specific and promote less ambiguity in the operationalization of the construct compared to definitions that broadly refer to the workplace as the target of perceptions. Therefore, a revised definition of perceived safety climate is that it is individual level perceptions of co-worker commitment to safety, with commitment to safety expressed through enacted practices, policies, and procedures. Such a definition clearly informs the reader that perceived safety climate only exists at the individual level, that it consists of perceptions of fellow frontline employees, and that the behaviours assessed reflect *enacted* instead of *formal* policies, procedures, and practices. However, it should be noted that the definition does not inform what a ‘co-worker’ actually is. In the analyses, perceptions of co-workers at the group or facility level were not related to safety outcomes. This suggested that there was no cohesive co-worker climate which affected individual behaviour-outcome expectancies. It is unknown whether individual co-worker perceptions are directed more generally at fellow employees in the same workgroup, in the same facility, or whether the most palpable events involving fellow employees in multiple areas lead to the formation of these perceptions. The original competency framework the scale was based on referred to the co-worker level as ‘everyone’, which may be an accurate description of the target of employee perceptions despite my initial belief that these perceptions would be based solely on employees in the same workgroup. However, ‘everyone’ is a highly ambiguous term, and given items in the scale do appear to relate to similarly ranked employees (i.e. not supervisors or managers), I am still of the belief that ‘co-worker’ best describes the scale and the target of perceptions. Possibly, future research can more accurately ascertain the target/s of these individual, subjective perceptions of co-workers.

Due to the conceptual links with safety climate, items in a perceived safety climate scale can relate to the behavioural domains of standards, involvement, and communication, otherwise known as active practices/safety compliance, proactive practices/safety participation, and declarative practices. This approach was used in the current study, and was effective in the prediction of safety outcomes. A secondary benefit of this approach is that a safety climate scale assessing perceptions of supervisors or managers needs only minor alterations for it to measure perceived safety climate. Additionally, it allows the researcher to investigate whether deficiencies in certain behavioural domains at higher levels of the organisation result in similar deficiencies at the lowest level of the organisation.

To further outline this proposed conceptualisation of perceived safety climate, some discussion on what causes perceived safety climate perceptions, what the perceptions represent, and how they affect behaviour is warranted. A detailed description in Zohar’s Multilevel Model of Safety Climate is one of the primary strengths of his model, as it clearly defined the boundaries of the construct and made possible the testing of key components of his model. Based on the study’s path and mediation analyses, it appears that perceived safety climate is predicted by management and supervisor commitment to safety. For example, if supervisors and management reward speed over safety, it is likely that co-worker behaviour will reflect this priority. However, individual level variance was also very important, reflecting the fact that individual climate perceptions are affected by worldviews, perceptual biases, and previous experience (Ostroff & Bowen, 2000). Hence, while higher level climates affect the behaviour of frontline employees, which in turn affect an employee's perception of co-workers and thus their perceived safety climate, these perceptions are subjective in nature. In comparison, safety climate is a more pervasive group-level phenomena (Kozlowski & Klein, 2000) rooted in a more objective reality (Zohar, 2003).

These perceived safety climate perceptions serve to inform the behaviour of an employee. If an employee perceives that co-workers generally treat safety as a low priority, they will be likely to act in a manner congruent with the perceived low priority of safety so as to adhere to the behavioural norms present. The following three steps describe the process by which safety climate and perceived safety climate lead to safety outcomes:

1. Co-worker behaviours are influenced by safety climates emerging from higher levels of the organisation.
2. These behaviours of co-workers are subjectively interpreted by individual employees, resulting in an understanding of "the way we do things around here" [perceived safety climate].
3. This subjective interpretation acts as a motivational driver, directing individual behaviour and thus the likelihood of becoming injured.

While there are other possible interpretations for the co-worker results, for example co-worker perceptions acting as a proxy for individual behaviour, there is no direct evidence for such speculation and so it will not be part of this proposed conceptualisation of the construct. Hence, in this description of the construct there are not many deviations to existing perceived safety climate theory. The main change to theory is in the focus of perceptions being on co-workers, rather than the workplace in general, therefore distinguishing perceived safety climate from aggregated safety climate.

The final suggestion to improve the perceived safety climate literature is that multilevel corrections should be implemented to analyses to control for any dependency in perceptions at higher levels. While perceived safety climate is an individual level variable, due to the shared nature of experiences in the organisational setting it cannot be said there is complete independence of observations. In the current study it was found that controlling for higher level variance resulted in slightly lower regression coefficients and higher standard error. While the results were more conservative, co-worker safety climate still managed significant associations with self-reported near misses, indicating that controlling for higher level variance does not suddenly invalidate the construct. By controlling for higher level variance it eliminates the possibility that higher level effects were the cause of any associations, resulting in more defensible conclusions.

Currently in the literature, perceived safety climate is the methodologically unsound sibling of safety climate, the apparent progeny of safety climate research in which aggregation was not possible and where the results may be confounded by the innate dependency in perceptions. Rather than suggesting the abandonment of the construct, my proposed conceptualisation suggests that research can flourish if certain conceptual and methodological changes are made to distinguish it from safety climate and improve the defensibility of conclusions. By focusing on co-workers, ambiguity in the literature is reduced since previously perceived safety climate was assessed as simply a non-aggregated, dimensionally equivalent form of safety climate. Such an approach was found to be untenable in the current study, since the pattern of relationships at the individual level were found to be different at the aggregate level. By focusing on these subjective perceptions of co-worker commitment to safety, and by correcting for higher level variance, the construct's role as a mediating variable between safety climate and safety outcomes represents an important avenue of future research.

10.5.2 Other Areas for Future Research

The current study provided support for Zohar's Multilevel Model of Safety Climate and additionally suggested that individual perceptions of co-workers mediate the relationship between safety climate and safety outcomes. However, as previously stated, some of the findings lack credibility due to the previously mentioned limitations, and so my proposed extension to Zohar's model requires replication before it can be seriously considered. Analyses involving the manager scale were the most inconclusive due to the small facility level sample size, and so the pattern of relationships that manager safety climate has with co-worker safety climate will need to be investigated. It is possible that with a larger facility level sample size, the associations that co-worker safety climate has with safety outcomes may diminish or disappear, with higher level variance being more important in the prediction of injury. Therefore, only through the replication of the analyses will it be known whether perceived safety climate deserves a place as a distinct predictor of safety outcomes. Preferably, this replication will involve better quality outcome variables, since only self-reported safety outcomes were available in the current study. No associations were found between safety climate and self-reported injuries/minor injuries, and so it is possible that the significant associations with self-reported near misses were not due to it being the most frequently occurring safety outcome, but because of common-method variance. Only through replication with objective injury data will this possibility be ruled out. Secondly, the analyses suggesting an extension to Zohar's model to include perceived safety climate were all conducted using a cross-sectional design due to an insufficient number of respondents completing the individual data linking item. This increases the possibility of common method variance confounding results and does not reveal whether perceptions of co-workers predict injury, or whether experience of injury predicts perceptions or co-workers.

Multilevel analyses examining the cross-level effects of safety climate also need to be conducted in a diverse range of industries to examine whether this affects the pattern of results involving supervisors and co-workers. While previous multilevel studies have not examined the role of co-workers, they have been performed in industries which are highly supervised, such as manufacturing, and so the strong associations found between supervisor safety climate and safety outcomes are not surprising. The current study was conducted in similarly highly supervised environment, potentially explaining the proximal supervisor influence on group safety outcomes and the comparative lack of associations between group-level co-worker safety climate and safety outcomes. While Newman and colleagues demonstrated that supervisors do not need to be closely observing behaviour and rewarding/punishing employees for them to be influential, their study was conducted in the driving context, with driving primarily an individual activity with less opportunity for co-worker behavioural modelling compared to other industries. Therefore, there needs to be further investigation in industries which are less highly supervised to determine if co-worker perceptions at the group level are a stronger predictor of safety outcomes. For example, Turner and colleagues found that co-workers were the most salient social force in promoting safety in demanding conditions compared to supervisors and managers in the railway maintenance context. The authors suggested that this was due to the less formal presence of supervisors in the industry compared to the more proximal and numerous co-workers. While the analyses were all conducted on the individual level and did not acknowledge the dependency in perceptions, future multilevel analyses in a similar industry may provide the same pattern of results. Similarly, the healthcare industry may be another environment in which co-workers are more influential. Research has shown that nurses are highly autonomous in their work (Bahadori & Fitzpatrick, 2009), and so it is possible that co-worker based group norms are more influential than supervisors or managers. This may especially be the case among nurse assistants, who operate with little direct supervision (Joel, 2006).

Further research needs to determine whether the association between safety climate and safety outcomes is mediated by individual level variables such as knowledge and motivation. While Zohar does not explicitly include such variables in his studies, a number of other researchers believe that safety climate indirectly affects safety outcomes (Neal & Griffin, 2006; Flin, 2007; Christian et al., 2009). It is difficult to draw conclusions about these disparate findings due to large differences in the operationalization of safety climate between the studies, however Flin suggests that the two perspectives are compatible since the behaviour-outcome expectancies referred to (yet not measured) in Zohar's model serve as an individual motivator. Though the current study was not able to reconcile these perspectives since safety motivation was not assessed, what it did find was that a different individual variable, perceived safety climate, mediated the relationship between safety climate and safety outcomes. Like safety motivation, it is possible that these subjective perceptions of co-workers serve a motivational role, with employees who perceive that co-workers prioritise safety more motivated to act in a similar manner. It remains to be seen whether perceived safety climate and individual motivation are generally tapping into the same construct, or whether they each represent a distinct step in the safety climate to injury relationship. Hence, further research is required to examine whether safety motivation acts as mediator, preferably with a behaviour-based and multilevel operationalization of safety climate so that methodological factors can be ruled out as the cause of the conflicting results between these two perspectives.

10.6 Proposed Safety Climate Model

Based on the findings of the current study, an extended version of Zohar's safety climate model is proposed (See Figure 18). This model combines safety climate and perceived safety climate into the one model through the inclusion of individual level perceptions of co-worker commitment to safety.

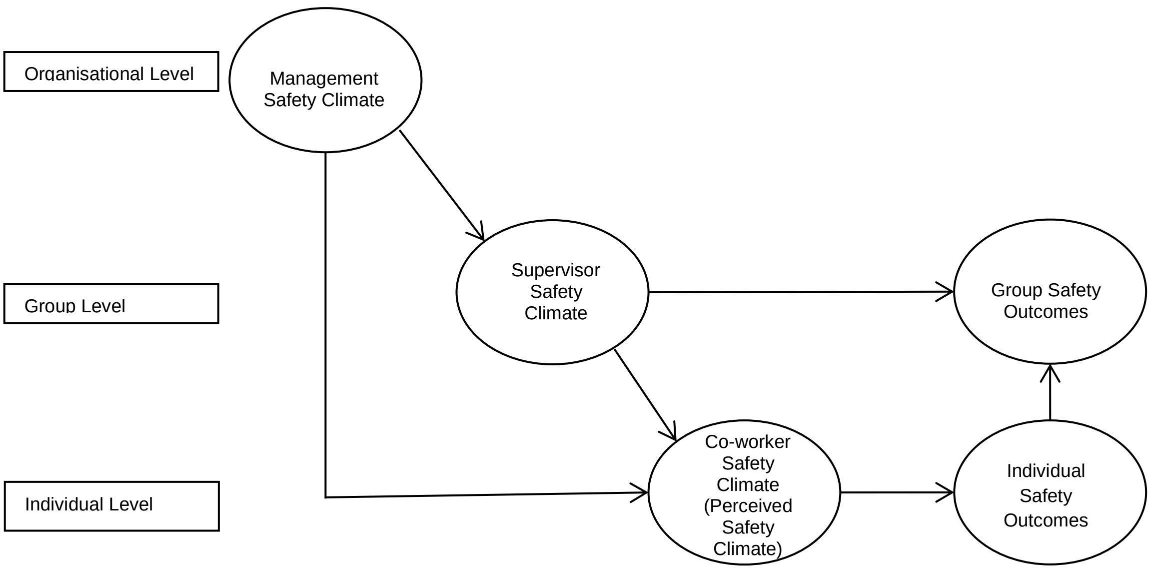

Figure 18. Proposed Safety Climate Model.

Most aspects of this model have been previously discussed, and so will not be repeated in great detail. The organisational and group levels of the model remain the same as Zohar's Multilevel Model of Safety Climate; climate perceptions stem from management and their enacted policies, practices and procedures. This was demonstrated in the current study by the strong associations between management safety climate and lower levels of climate in the path analyses. While sample size problems, particularly when multilevel analyses were conducted, prevented firm conclusions being made, a large body of research supports this central role of management as the origin of climate and culture (Hofstede et al., 1993; Flin, Mearns, O'Connor, & Bryden, 2000; Zohar & Luria, 2005; Zohar, 2003; Arboleda, Morrow, Crum, & Shelley, 2003). Hence, in the model there is a path from manager safety climate to supervisor safety climate and co-worker safety climate.

Given that policies and procedures do not cover every eventuality, supervisory discretion results in a separate group level safety climate, as per Zohar's model. Supervisors directly predict group level safety outcomes, mediating the relationship between manager safety climate and group level safety outcomes. This is due to proximity of supervisors in comparison to managers, which provides them the opportunity to punish and reward behaviour and therefore be a more influential source of behaviour-outcome expectancies. This was demonstrated in the current study by the predictive validity of the supervisor scale at the group level, and the path analysis results. The path analyses reflected the findings of Zohar and Luria, in that the model in which manager safety climate directly predicted the self-reported incident frequency factor displayed poorer fit indices compared to the model in which this path was removed. Though the multilevel mediation analyses did not support this relationship, they did find that supervisor safety climate predicted safety outcomes, and that the relationship between manager safety climate and safety outcomes became non-significant when supervisor safety climate was included. It is likely that an inadequate sample size prevented the association between manager safety climate and supervisor safety climate from being correctly estimated.

The aforementioned findings all reflected previous research and theory, and while they provided much needed support for some of Zohar’s non-replicated findings, they did not extend understanding of the construct. In comparison, the extension of Zohar’s model to include perceived safety climate may promote conceptual development of both safety climate and perceived safety climate. This extension was based on the finding that at the individual level the co-worker scale achieved the strongest associations with safety outcomes, even after controlling for higher level variance. This thesis further found that the relationship between group level supervisor safety climate and safety outcomes was mediated by individual level co-worker safety climate, in other words, perceived safety climate. While previous research has assessed perceived safety climate through the same dimensions as safety climate, the stronger associations at the individual level suggested that co-workers are a more suitable subject of individual level perceptions. Additionally, by not assessing perceptions of supervisors and managers at the individual level, future research will potentially be less ambiguous and more methodologically sound. What these findings suggested was that individual variance was important in the prediction of individual safety outcomes, with an individual’s subjective perceptions of the priority of safety among co-workers being the most proximal indicator of safety outcomes. Therefore, the model shows a direct path from perceived safety climate to individual safety outcomes, with employee’s behaviour reflecting the perceived norms of follow co-workers. If an employee’s behaviour reflects a perceived low priority of safety among co-workers then their likelihood of becoming injured increases, due to the majority of accidents resulting from human behaviour (Reason, 1990). The paths from manager and supervisor safety climate to perceived safety climate reflects frontline employee behaviour being the product of higher levels climates, which when combined with individual characteristics and experiences, results in the formation of an individual’s subjective perception of co-workers which directs their own behaviour. These paths were partially supported by study findings, with the previously mentioned sample size and level of analysis problems producing some uncertainty. While the path analyses demonstrated strong associations between manager safety climate and co-worker safety climate, both dimensions were aggregated to a level inconsistent with the proposed model.

When multilevel analyses were conducted, facility level variance was not able to be estimated, and therefore the addition of this link was on theoretical considerations rather than on empirical grounds. It is also possible that the path from manager safety climate to perceived safety climate is completely mediated by supervisor safety climate, a continuation of the multilevel cascade model described by Zohar and Luria. Multilevel analyses were able to establish a link between group level supervisor safety climate and perceived safety climate, however given that manager safety climate was not able to be adequately estimated, it is uncertain whether this path was necessary. However, given previous research which has demonstrated the proximal influence of supervisors on individual level safety outcomes (Zohar, 2000; Newman, Griffin, & Mason, 2008), it unlikely that perceived safety climate is solely the product of manager safety climate. Overall, this pattern of relationships between manager, supervisor, and co-worker safety climate represents the area of most ambiguity in the proposed model. While all attempts were made to unravel these cross-level effects, the inconsistency in results points to the need for future research to shed light on the antecedents of perceived safety climate.

The final path is between individual level safety outcomes and group level safety outcomes. This path stems from the fact that an increased individual injury rate would also increase a group's injury rate. Overall, depending on the level of safety outcomes, different levels of the organisation are the most proximal predictor. At the group level, the supervisor scale is the most proximal predictor, with facility level manager safety climate and group level co-worker climate demonstrating weaker associations. For individual level safety outcomes, individual perceptions of co-workers are the strongest predictor, reflecting the importance of individual characteristics in predicting individual safety outcomes. While some paths require further supporting evidence, the description of this extended conceptual model provides a starting point for future research to assess the relationship between safety climate, perceived safety climate, and safety outcomes.

10.7 Practical Implications

Possibly the most important implications to come from the study is in terms of research methodology. This has been discussed in detail previously, and so will only be briefly summarised. What the study found was that the pattern of relationships at the individual level are different to those at the aggregate level, providing strong evidence that perceived safety climate and safety climate are distinct constructs. This finding suggests that researchers and journal editors need to be more vigilant when it comes to the labelling of these constructs, as allowing individually operationalized (perceived) safety climate to be labelled safety climate promotes ambiguity in the literature. The analyses additionally found that regression coefficients tended to be larger and standard error smaller when the dependency in climate perceptions was not accounted for. Hence, to avoid an overestimation of the association between perceived safety climate and safety outcomes, multilevel corrections should be employed if possible. If the corrections are not possible, for example in organisations where group level identifiers are not available, then a more conservative p value should suffice.

The findings also have a number of practical implications for organisations. In this study a multilevel safety climate survey was used in the oil and gas context, demonstrating overall good psychometric properties. While sample size was a problem in some analyses, the findings overall demonstrated that Zohar's Multilevel Model of Safety Climate was applicable to the oil and gas industry. Since there are substantial differences in the context where Zohar tested his model and the current study, the findings suggest that the model is relatively robust, with the potential to be utilised in a wide range of industries. Given these findings and the significant methodological advantages of a multilevel survey, other organisations should have the confidence to utilise similar multilevel surveys in the diagnosis of potential safety problems. Unlike scales similar to Neal and Griffin's (2006), in which only manager commitment to safety was assessed and no specific behaviours listed, in a multilevel behaviour based scale much more practicable information can be procured by the organisation. The scale can tell the organisation what specific behaviours are underperformed at what level of the organisation, which can form the basis for future behaviour-based interventions (see Geller, 2005), or possibly changes to policies, procedures, or practices.

Importantly, the findings showed that adhering to Zohar's Multilevel Model of Safety Climate does not necessarily mean using his scales. The survey used in the current study assessed similar dimensions and used a similar itemisation, but was developed to be aligned with the specific organisational needs and context in mind. Therefore, other organisations can draw upon Zohar's model in the development of safety climate surveys, and include context specific items to increase the sensitivity of the survey. By listing behaviours relating to active, proactive, and declarative practices, or as the current survey refers to as standards, involvement, and communication, other organisations can develop a relevant and practicable survey to assist in the reduction of injuries.

The results additionally demonstrate the importance of not focusing on one level of the organisation when planning safety initiatives. Each level of the organisation was found to be important in different ways. Manager safety climate is regarded as the antecedent of lower level climates in the organisation (Hofstede et al., 1993; Flin, Mearns, O'Connor, & Bryden, 2000), a view supported by the path models which showed strong associations between manager safety climate and supervisor/co-worker safety climate. Supervisors are also deemed to be an important proximal influence on behaviour due to their ability to punish/reward behaviour, which was similarly supported by significant associations between supervisor safety climate and group level near misses the subsequent year. Finally, perceptions of co-workers appeared to be an important influence on the individual level, being the most proximal predictor of individual level self-reported near misses. Therefore, the study has shown that organisations should take a holistic approach to the prevention of injury by targeting behaviours at all levels of the organisation. This view is echoed by Turner and colleagues (2010, p. 489) , who states that "…focusing on one source of safety-related support (e.g., supervisors, senior management) may not be capturing the full range of sources of supports available, and that these social influences have the possibility of reinforcing one another under varying job conditions". Turner and colleagues found that co-worker support was not influential when job demands were low; however in demanding conditions they had a larger role in preventing hazardous work events compared to supervisors or managers. Hence, certain contexts and job conditions can interact with different levels of the organisation in the prediction of injury, and so adhering to a multilevel perspective of injury prevention will likely lead to the best outcomes for employees.

10.8 Conclusion

In this thesis, an attempt was made to replicate and extend upon Zohar's Multilevel Model of Safety Climate, thereby providing insight into the lagged and cross-level relationships safety climate has with safety outcomes. Additionally, given the substantial methodological differences apparent among studies in the literature, the effect of level-of-analysis and analytical technique were investigated. While the thesis was ironically not immune to methodological deficiencies of its own, with sample size related problems preventing a true longitudinal design and clear-cut conclusions to be made from facility level analyses, the results generally supported Zohar's model. This importantly suggested that the model generalised beyond the manufacturing context wherein it was tested, and could be applied to the Australian oil and gas context.

The thesis also importantly suggested that Zohar's model could be extended to include perceptions of co-worker commitment to safety, though not at the group level as originally envisioned. Multilevel analyses demonstrated that at the individual level, perceptions of co-workers were the strongest predictor of individual safety outcomes, and were more proximal than group level perceptions of supervisor commitment to safety. This finding demonstrated that individual level climate perceptions (i.e. perceived safety climate) display a different pattern of results as compared to aggregated safety climate perceptions. The finding thereby provides a strong case for the two constructs to be considered conceptually distinct, rather than the same construct assessed at different levels of analysis. An attempt was made to separately define and conceptualise perceived safety climate to clarify its distinctiveness from safety climate, in the hope that the ambiguity which befell the organisational climate literature does not similarly impede the conceptual development of safety climate. Therefore, despite the limitations of some of the analyses, this thesis has contributed to the literature by providing evidence of perceived safety climate being a separate level in Zohar's Multilevel Model of Safety Climate. Replications of these findings are required to cement perceived safety climate's place as an important, distinct predictor of safety outcomes.

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Appendix A

Additional Confirmatory Factor Analysis Results

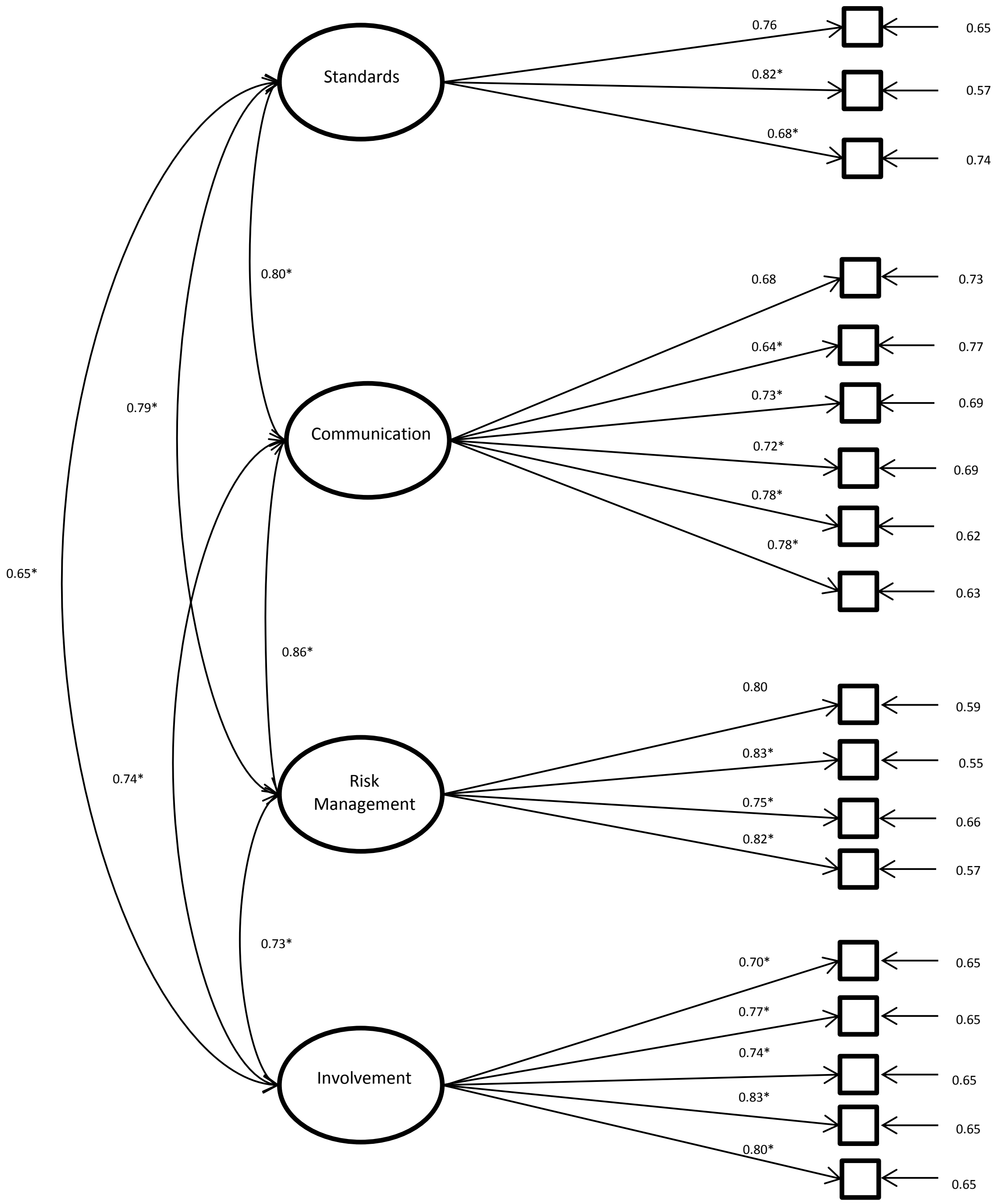


Figure A1. Measurement Model for Co-worker Scale.

Table A1

Comparison of Models using Robust Fit Statistics (Year 2)

Model	S-B χ^2	df	S-B χ^2 /df	CFI	NNFI	RMSEA	AIC
Cut-off Criteria			< 3	= / >.85	= / >.85	= / <.08	*
Co-Worker Scale							
Four Factor Uncorrelated	1726.92	135	12.79	.67	.63	.14	1456.95
One Factor	869.10	153	5.68	.85	.83	.09	599.10
Four Factor Correlated	450.55	129	3.49	.93	.92	.06	192.55
Supervisor Scale							
Four Factor Uncorrelated	2013.06	135	14.91	.64	.60	.15	1743.06
One Factor	541.82	135	4.01	.92	.91	.07	271.82
Four Factor Correlated	369.39	129	2.86	.96	.95	.06	107.39
Manager Scale							
Four Factor Uncorrelated	2447.46	209	11.71	.72	.69	.13	2029.46
One Factor	778.45	209	3.72	.93	.92	.07	360.45
Four Factor Correlated	601.20	203	2.96	.95	.94	.06	195.21

Note: S-Bχ^2= Satorra-Bentler Chi-square statistic, S-Bχ^2 /df = Satorra-Bentler chi-square divided by degrees of freedom, CFI = Comparative Fit Index, NNFI = Non-normed Fit Index, RMSEA = Root Mean Square Error of Approximation, AIC = Akaike’s Information Criterion, * = a lower AIC indicates a better fit.

Table A2

Comparison of Models to test Participant's Differentiation of Scales

Model	S-B χ^2	df	S-B χ^2 /df	CFI	NNFI	RMSEA	AIC
Cut-off Criteria			< 3	= / >.85	= / >.85	= / <.08	*
One Factor	1438.32	54	26.64	.74	.68	.19	1330.32
Three Factor	174.59	51	3.4	.98	.97	.06	72.59

Appendix B

Facility-Level Co-worker Scale Results

Table A3

Cross-sectional Multilevel Logistic Regression Analyses between Co-worker Safety Climate and Injury

	Near Miss Estimate (SE)	p Value	Injury Estimate (SE)	p Value
Co-worker Scale	-1.074 (0.809)	0.184	0.652 (0.555)	0.240
Standards	-0.742 (0.772)	0.336	0.700 (0.478)	0.143
Communication	-0.986 (0.889)	0.267	0.453 (0.652)	0.488
Risk Management	-0.896 (0.817)	0.273	0.716 (0.506)	0.158
Involvement	-1.392 (0.690)	0.044*	0.512 (0.544)	0.346

*p < 0.05

Table A4

Spearman's Rho Correlations between Co-worker Safety Climate and Self-reported Safety Outcomes (N = 9)

	Near Miss Correlation Coefficient	p Value	Injury Correlation Coefficient	p Value
Co-worker Scale	0.033	0.466	-0.150	0.350
Standards	-0.150	0.350	-0.267	0.244
Communication	-0.117	0.383	-0.200	0.303
Risk Management	0.067	0.432	-0.083	0.416
Involvement	0.217	0.288	0.033	0.466

Table A5

Spearman's Rho Correlations between Co-worker Safety Climate and Official Injury Statistics (N = 8)

	Minor Injury Correlation Coefficient	p Value	Injury Correlation Coefficient	p Value
Co-worker Scale	0.167	0.347	0.381	0.176
Standards	0.238	0.285	0.190	0.326
Communication	0.167	0.347	-0.048	0.455
Risk Management	-0.167	0.347	0.524	0.091
Involvement	0.619	0.051	0.619	0.051

Appendix C

Self-Reported and Official Injury Statistics Comparisons

Table A6

Comparisons between Self-Reported and Official Injury Statistics for each Facility in the Organisation (Year 2)

	Minor Injury Mean (SR)	Minor Injury Mean (O)	Injury Mean (SR)	Injury Mean (O)
Facility 1	.60	.170	.04	.010
Facility 2	.69	.108	.08	.031
Facility 3	.41	.117	.04	.017
Facility 4	.17	-	.0	-
Facility 5	.57	.114	.17	.038
Facility 6	2.40	.295	.47	.067
Facility 7	.52	.149	.09	.014
Facility 8	1.24	.135	.21	.014
Facility 9	.23	.004	.05	.0

SR = Self-Reported, O = Official data

Appendix D

Distributions of Outcome Variables

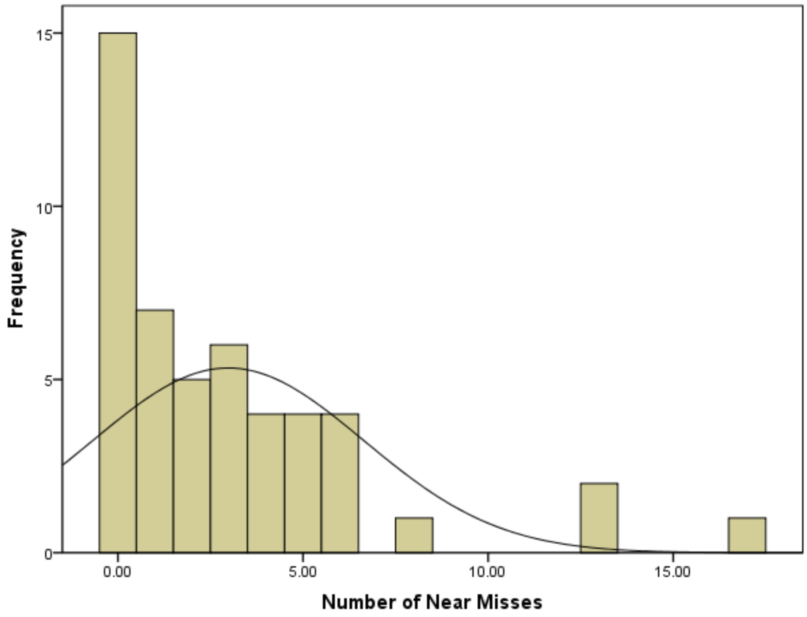


Figure A2. Frequency of Near Misses Reported at the Group Level (N = 49).

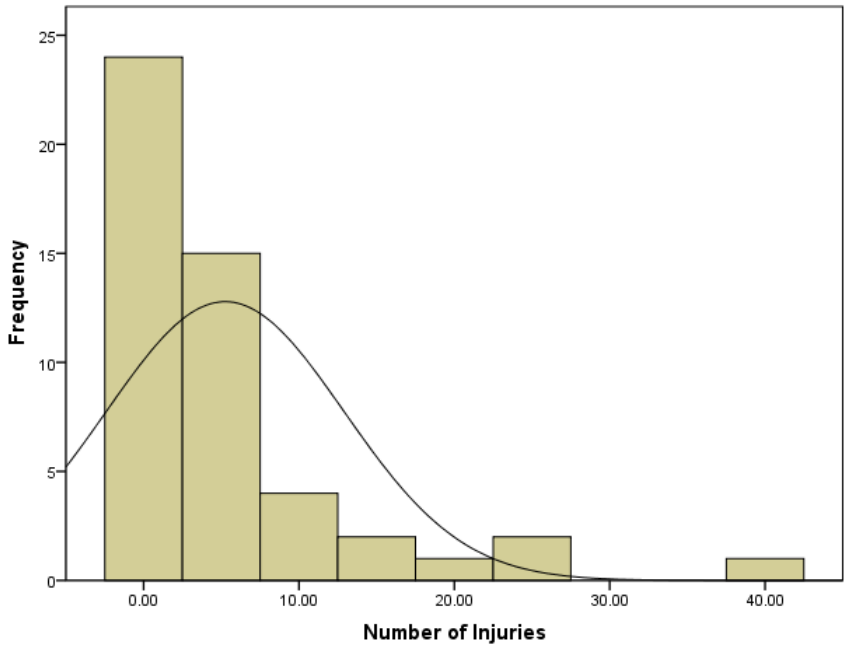


Figure A3. Frequency of Injuries Reported at the Group Level (N = 49).

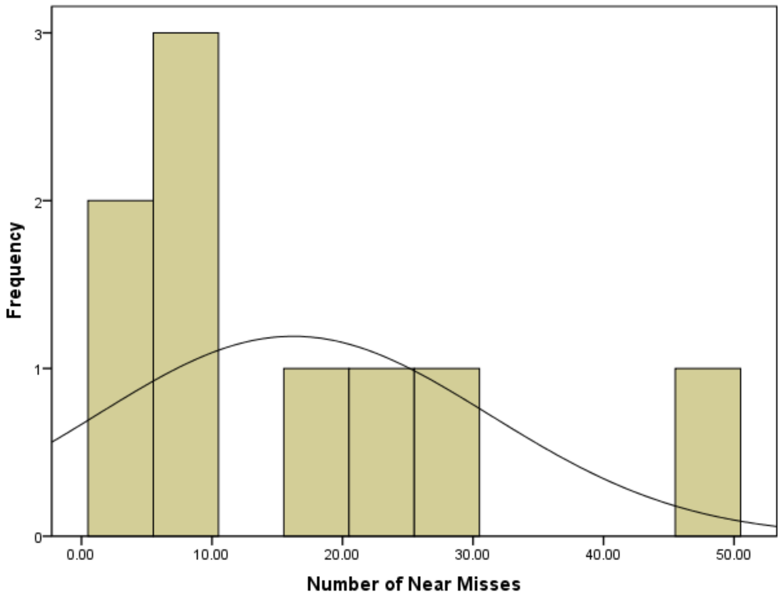


Figure A4. Frequency of Near Misses Reported at the Facility (N =9)

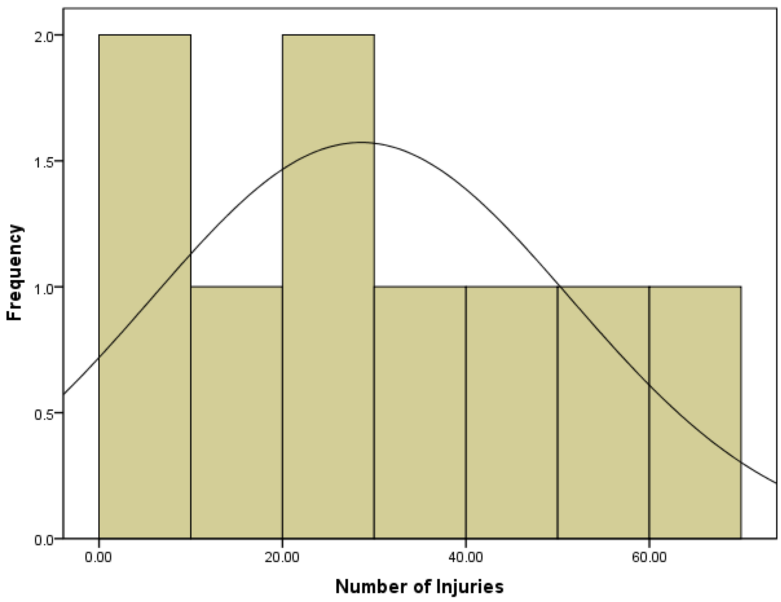
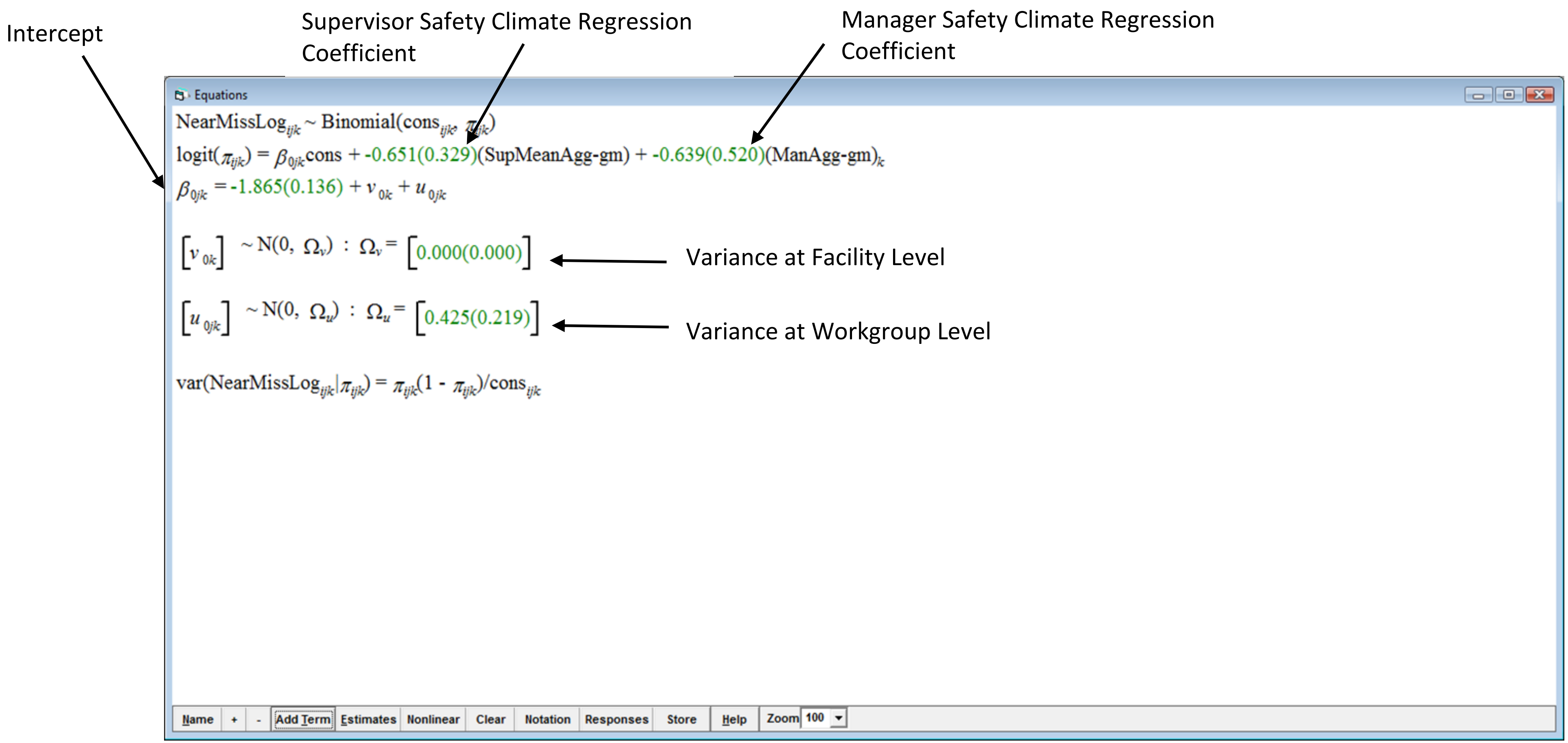


Figure A5. Frequency of Injuries Reported at the Facility Level (N = 9)

Appendix E

Annotated Printout of Mediation Analysis Performed in MlwiN



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