Safety Communication Patterns in Small Work Groups – A Pilot Study Using Social Network Analysis

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Abstract

As a project based industry, construction is portrayed through the short term and transitory nature of the industry. This is one of the factors that have been correlated to the poor safety performance of the construction industry. An essential part of safety performance, however, is the effective safety communication between all parties on construction projects. The construction industry is highly regulated due to its high incidence of work-place accidents. This is especially true of smaller building companies/enterprises where the burden of compliance to safety regulations is most onerous. The majority of current research in this topic area has focused on identifying the high risk components or the causes of increased risks. The literature on safety communication network patterns and its relation to safety performance is nevertheless minimal. Thus, this study takes the opportunity to explore the safety communication issue by analyzing the communications patterns in small workgroups. In a pilot study, through surveys with construction crews that are contributing to active construction projects in Sydney, Australia, patterns of safety communications were identified using social network analysis (SNA). The findings, though preliminary, has identified safety communication network patterns under formal communications and toolbox talks may determine a small group's safety performance.

Keywords: Social network analysis (SNA), Communication, Safety, Construction projects, Australia

1 Introduction

The construction industry is one of the most injury prone industries worldwide (Kines *et al*., 2010). As of 2011-12 the construction industry constituted about 9% of the Australian workforce (1.01 million people). The industry however accounted for about 11% of all of the serious workers' compensation claims. Additionally over 5 years from 2007-08 to 2011-12 there were 211 fatalities of construction workers resulting from work-related injuries. This corresponds to a fatality rate of 4.34 fatalities per 100,000 workers, nearly twice the national rate of 2.29 for all industries (Safe Work Australia, 2012). Furthermore, in 2010 56.3% of the construction fatalities, within the US occurred in establishments that employ less than 20 employees, and yet they only employed 41.4% of the wage-salary workforce in construction (The Center for Construction Research and Training, 2013). This indicates that small work groups within the construction industry have exceptionally poor incident rates. There is also evidence that small businesses struggle to understand their obligations under principle-based Occupational Health and Safety (OHS) legislation. This is significant in the construction industry as the majority of the construction businesses employ five or fewer people (Loosemore and Andonakis, 2007). Safe workplace practice is also compromised due to Work Health and Safety (WHS) not always being a high priority in the planning of a project. It is often seen as an additional cost on their already thin profit margin (Wadick, 2010).

The construction industry is a project based industry that incorporates many trades and practices into a complex and interdependent system. A project based interdependent industry is heavily reliant on communications between the groups and individuals. The communications enable people, tasks, processes, and systems to interact with each other in a purposeful and co-operative way. A large part of this communication involves the exchange of information related to safety. Effective and constructive safety communication can help prevent at-risk behaviours and promote safe work practices (Vecchio-Sadus, 2007).

The construction industry requires greater attention to communication and safety than most other industries due to its short term and transitory nature, and the complexity and diversity of the projects (Sawacha *et al.*, 1999). These factors have contributed to the construction industry being over represented in the workplace injury and death statistics. The majority of incidents that occur on construction sites are related to the field level employees. Safety communications and discussions can help to promote the essence of safety (Sawacha *et al.*, 1999).

An effective method to analyse a group for their effective safety communication network patterns is through the use of Social Network Analysis (SNA). SNA creates a communication network that can provide an understanding of the supportive framework for the interactions that if improved along with safety communications, can help to prevent at-risk behaviours and enhance safety culture (Vecchio-Sadus, 2007). This method of analysis employs a set of techniques that involve representing the relationships between a set of nodes or actors, as well as its structural characteristics (Pryke, 2012). Thus through SNA it is possible to identify 'strong' and 'poor' safety communication network structures and apply these findings to the Safety performance findings.

Work Health and Safety (WHS) within a workplace has been a topical area for industries as a whole and specifically in the construction industry. The previous literature tended to focus on identifying the high risk components of the industries or the causes of increased risks within an industry (Wang *et al.*, 2013; Zhou *et al.*, 2014). There are fewer studies on safety communication network patterns within a workplace and its relationship to workplace safety performance (Alsamadani *et al.*, 2013; Kines *et al.*, 2010), and these studies have not been performed for the Australian construction industry. This gap of safety communications within the Australian on-site construction workplace and its relationship to workplace safety has been identified as the focus of this study. This study is therefore aimed at determining whether there is a relationship between safety communication network patterns (e.g. interconnections and member dominance) and safety performance within small groups of the Australian construction industry.

2 Literature Review

2.1 Communication and Occupational Health and Safety

Handling health and safety necessitates good skills in communication (Holt, 2005). The use of effective methods of communication and information transfer between employees and management has been shown to return an increase in the safety standards as well as improving the achievement of safety policies (Teo *et al.*, 2005).

The manner in which safety is communicated will have an influence on whether or not the safety processes are partaken or understood (Vecchio-Sadus, 2007). This is shown in a study performed by Loosemore and Andonakis (2007) which indicates that under the principle-based OHS legislations the responsibilities given to the small businesses are often misunderstood. This particular challenge is of significant importance in relation to the construction industry, as the majority of its businesses consist of 5 or less people being employed. Furthermore, the main contractors of the project may transfer over all of the safety responsibilities to the sub-contractors without ensuring that they have the capacity to maintain these and keep a safe working environment (Teo *et al.*, 2005).

The purpose of safety communications are in their most general sense intended to improve safety to eliminate or at least reduce occurrences that result in injury or illness (Wogalter *et al.*, 1999). Vecchio-Sadus (2007) stated that effective communication skills are able to decrease the probability of an injury as well as promote safe behaviours. Safety communication can also be seen as a means of shifting safety responsibility to others where hazards cannot be adequately guarded. This is not then the limitation of their responsibility, however. The second argument for maintaining constant effective safety communications is the workers' rights to know of the hazards within their workplace (Wogalter *et al.*, 1999).

Vecchio-Sadus (2007) stated that it is not as simple as training people to partake in safety processes and to work safely. It is sometimes necessary to provide some motivation to partake in safe working. It is of importance that an atmosphere promoting safe behaviour is introduced which reinforces the benefits for the organisation and for the employees.

2.2 Safety Communications in the Construction Industry

Construction sites are still one of the most accident prone and hazardous workplaces to be a part of (Teo *et al.*, 2005). Developing a safety culture and improving the safety performance is a current challenge for the Australian construction industry. This is of particular importance in Australia in part due to Australia's largely diverse and multicultural workforce that is represented (Biggs and Biggs, 2013). Groups with greater diversity of culture and language have an increased need of consistent and effective safety communication (Alsamadani *et al.*, 2013) as these can form 'barriers' to achieving a safe work environment (Loosemore and Andonakis, 2007).

It has been found that accidents on construction sites have an increased probability of occurring if there are insufficient company policies, poor attitudes presented by the construction personnel, unsafe practices, workers with inadequate safety knowledge and training, and a poor management commitment (Sawacha *et al.*, 1999; Teo *et al.*, 2005). This is further shown throughout the construction industry, by workers characterised as frequently utilising the principle that the benefits of operating safely are not as palpable as the benefits of meeting production outputs and time/cost charts (Biggs *et al.*, 2013), or that of maximum expected utility, where the benefits of safe behaviour often get outweighed by the benefits of unsafe behaviour. This is often due to a fear that the slower paced work or safe behaviour may lead to lower wages and/or penalties (Kines *et al.*, 2010). An increasing amount of the reliance for the liability of the compensation claims, for contractors within the construction industry, has been shifting over from the companies themselves to insurance companies. This shift may lead to inadequate site safety training and supervision for the workers and instead obtaining insurance (Teo *et al.*, 2005).

Communications are important in forming a safe work environment at the workplace through the exchange of information about hazards and risk control methods. Safety communications are also essential to aid in influencing attitudes and behaviours within the workplace (Vecchio-Sadus, 2007). Engaging staff in safety activities to gain cooperation and support towards the safety culture of the group is critical and effective safety communications are essential for this (Vecchio-Sadus, 2007).

A study showed, however, that only 6-16% of the verbal exchanges between foremen and the workers were related to safety (Kines *et al.*, 2010). Other studies have stated that employees will be more comfortable with engaging in safety communications when a framework for communication and consultation has been created that encourages individuals to report hazards, incidents and near misses. The studies also ratify that in order to acquire a better safety performance and a better physical safety level there should be regular talks on site, between site managers or supervisors and the on-site workers (Kines *et al.*, 2010). They also point out, that training workers appropriately also leads to improved safety performance (Sawacha *et al.*, 1999). Organisations that exhibit positive safety cultures are often characterised by having a solid base for their communications. This base is usually trust and shared perceptions of the importance of safety (Vecchio-Sadus, 2007). A study by Vecchio-Sadus (2007) noted that one of the drivers of safety communication is shifting safety responsibilities to others when the hazard cannot be adequately guarded. As a basis he states that in order to decrease the probability of any workplace injuries it is beneficial to have effective communication skills.

Construction Projects contain large amounts of sub-contractors on their sites at any given time. This large quantity of sub-contractors raises a concern for the construction management group in managing the process factors, in order to effectively maintain control and communication over these large numbers. It has been seen that as larger numbers of sub-contractors are presented so too are the chances of an accident occurrence (Teo *et al.*, 2005). This problem stems from the difficulty to maintain an effective communication network to and from the various sub-contractors, as there may be many levels of them, thus reducing coordination and control (Teo *et al.*, 2005).

Studies on the subject of exchanges between leaders and workers found that these interactions inspired employees to raise safety issues. Supervisory feedback and recognition were seen as one of the most influential incentives for job performance. Thus daily feedback from supervisors in relation to safety and unsafe behaviour exposed the priorities between production and safety (Kines *et al.*, 2010). Kines et al. (2010) concluded that by coaching construction foremen to include safety communications in their daily verbal exchanges with the workers that they had a positive and lasting effect on the safety levels, and thus for their safety performances.

2.3 Safety Communications Networks

This study includes some research into the communication network patterns that are present in each of the studied groups. Safety communication networks are the communication structures of a system or network (Sonquist, 1984). Communication networks identify the relationships or ties within the groups' network. This is to gain an understanding of human behaviour (Feld, 1982) with the process of mutual information exchange (Sonquist, 1984). This feature works by utilising tools, such as social network analysis (SNA), to obtain measures about the groups communicative interactions.

Social network analysis (SNA) provides a method of analysis of these safety communication network patterns. The analyses of these features vary greatly from what a traditional individualistic, variable-based approach can achieve. This is due to the traditional method of analysis calculations take into account only the individual characteristics of the subjects and ignores the broader context of interactions with the social networks connecting them to other subjects (Knoke and Yang, 2008; Sonquist, 1984). This means that the subjects are assumed to act without regard to the behaviour of the connected actors. However the connecting actors are known to influence each other through their connections (Knoke and Yang, 2008). Using SNA as a tool for the study of communication network patterns has grown considerably in the past decades (Knoke and Yang, 2008).

A notable article relating to the study of safety communication networks in the construction industry used SNA to identify the network characteristics (Alsamadani *et al.*, 2013), which have also been in this study. Another study, by Pryke (2004), studied the application of SNA with a focus on construction. This study found many benefits to the use of SNA in the appropriate study, such as the graphical representation of the analysis and also a detailed representation of the relationships that exist between actors. These studies show that SNA can be successfully implemented into the study of groups' communication network patterns within the construction industry.

The safety communication network patterns that are studied in this thesis are analysed in relation to the interconnections and the member dominance within the groups. These features are analysed using SNA as a tool to aid in the understanding of the effectiveness of these communication network patterns. All of these features have been included in a previous similar study about safety communication networks in small work crews and their safety performances (Alsamadani et al., 2013).

3 Theoretical Framework

A theoretical framework has been constructed from the preliminary findings based on the literature review, as shown in Figure 1. It graphically depicts the constructs that are analysed within the study. These constructs are measured in order to establish the performance of these variables and enable an evaluation of their relationships (Fellows and Liu, 2008).

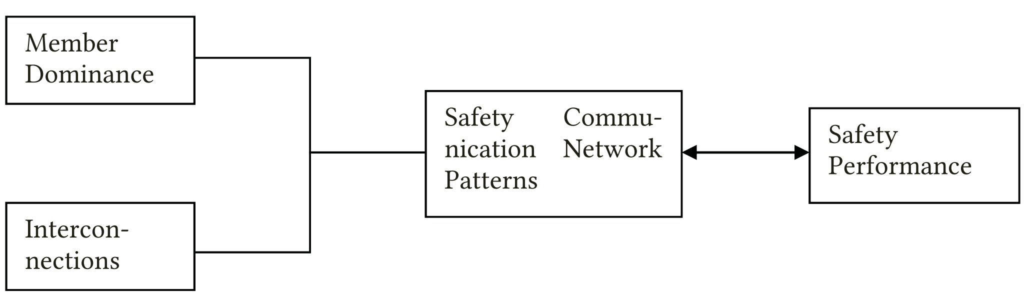


Figure 1 Theoretical Framework of relationships between safety performance and communication network patterns

The framework shows the hypothetic relationship between safety performance and safety communication network patterns. It also specifies two types of network patterns that are useful in demonstrate such relationship, including: (1) the interconnections of the groups' safety communication network; and (2) the member dominance of the groups' safety communication network. In the proposed framework the main connection is between safety performances and safety communication network patterns, which is supported by various past studies that noted the importance of safety communications on a work group's safety performance (Alsamadani *et al.*, 2013; Kines *et al.*, 2010; Le *et al.*, 2014; Sawacha *et al.*, 1999; Teo *et al.*, 2005; Vecchio-Sadus, 2007; Wong *et al.*, 1999). The major components of the theoretical framework are operationalized based on past similar research (Alsamadani *et al.*, 2013; Knoke and Yang, 2008) and shown in Table 1.

Table 1 Operationalization of Major Components of the Theoretical Framework

Constructs	Variables	Value
Safety Performance	Lost Time Injury Frequency Rate (LTIFR)	$\frac{\text{Number of lost time injuries}}{\text{million hours worked}}$
Communication Method	Mode of Communication	Formal Communication, Written Communications, Training, Toolbox Talks, Informal Discussions
Communication Frequency	Frequency of Communication	Monthly, Fortnightly, Weekly, Daily, Less than Daily
Interconnections	Network Density	Percentage
Member Dominance	Betweenness Centrality	Percentage
Member Dominance	Degree Centrality	Percentage

4 Research Methods

Data were collected via a questionnaire survey in this study. The questionnaires are aimed at uncovering the safety communication network patterns of the groups. To address the various methods of safety communications that can arise in the construction industry, both formal and informal communication types are considered. The formal communications model involves any safety knowledge that is shared through any pre-determined mediums. These mediums often involve written communications, formal presentations, toolbox talks, and training. The informal communications are modelled to incorporate any ad hoc communications between individual group members on site. These communications include notifying another member of a hazard while in passing without any pre-defined necessity.

The survey questionnaires for this study were administered in person to the participants. This method of administering questionnaires was chosen to ensure that all participants of the pilot study group completed the survey. It is important for everyone from the crew to participate. Otherwise critical participants may be missing from the data set. The survey participants were limited to field-level employees and field-level managers. Furthermore, an eligible group must work for the same employer (including contractors), in the same physical location, and working on the same project. In order to narrow the focus of the research and to avoid conflicts of interest, the research does not include the managers and or directors that are not part of the daily building team.

The questionnaire that will be used in this study has two sections. The first section of the questionnaire requests for the respondents' personal profile. Such data will be used to further determine the respondents' suitability for participation in this study. These questions involve the name of the project that the respondents are working on and their project role. The second section of the questionnaire addresses the safety communications between group members. The data will be utilised for analysing the safety communication network patterns. The data analysis will be conducted using Social Network Analysis software and techniques. This section focuses on how the individual members communicate or are communicated with and with whom. The respondents will be asked to fill in the names of the other group members and then denote the methods of safety communication with these members and the frequencies of those.

This study focuses on two types of network patterns in order to identify the relationships between safety communication network patterns of a group and their safety performance. The first type concerns the interconnections of the networks and their relevance to the safety performances of those groups. The second type relates to the trends between member dominance in the groups and their safety performances. Both of these two types of network patterns will be examined using social network analysis techniques. Correlation statistical analysis will then be conducted to reveal any significant correlative relationship between safety communication network patterns of a group and their safety performance. The proposed metrics associated with network patterns include centrality (both degree and betweenness) (associated with member dominance) and density (associated with interconnections). These metrics represent the heart of the constructs when modelling communication patterns (Alsamadani *et al.*, 2013).

Social network analysis is an analytical method that has been the topic of and used in many studies (Chinowsky et al., 2008; Chinowsky et al., 2010; Hartmann and Fischer, 2009; Haythornthwaite, 1996; Park et al., 2011; Pryke, 2012; Pryke, 2004; Ruan et al., 2013; Tatlonghari et al., 2012). However there have only been a few articles that have attempted to incorporate SNA into their studies of assessing the effectiveness of safety communication networks in the construction industry (Alsamadani et al., 2013; Le et al., 2014). These studies, however, where performed within the United States (US) and have not been performed to address the unique characteristics of the Australian construction industry.

5 Results and Analysis

In the pilot study, the data were collected from a small plumbing group in Sydney, Australia. The group consists of four field level employees and one field level manager. The group members were working for the same employer, in the same physical location, and on the same project. In order to narrow the focus of the research and to avoid conflicts of interest, the research does not include the managers/directors that are not part of the daily building team.

The safety performance is measured using Lost Time Injury Frequency Rates (LTIFR), which was estimated by the group manager. Lost time injuries is defined as the occurrences that resulted in a fatality, permanent disability or time lost from work of one day/shift or more (Standards Australia, 1990). The LTIFR of a group represents the number of lost time injuries that would occur in that group in every million hours worked. The average LTIFR of NSW was reported at 27.62 in 2012 (Ku-ring-gai Council, 2012). The LTIFR of the group, estimated by the group leader, was 1. This means that the group is estimated to have 1 lost time injury per million hours worked.

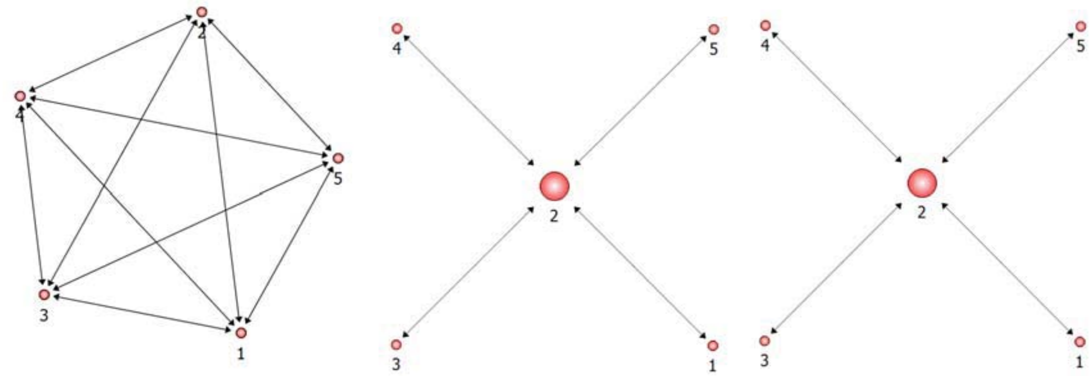
The interconnections of the safety communication networks of the pilot study group under different communication modes have been analysed using the measure of network density. The network density is measured from '0', being completely un-connected, to '1', being perfectly connected. The ideal situation for a group is to have a perfectly connected network. The values of the network density of the safety communication networks of the pilot study group under different communication modes are shown in Table 2.

Table 2 Interconnections

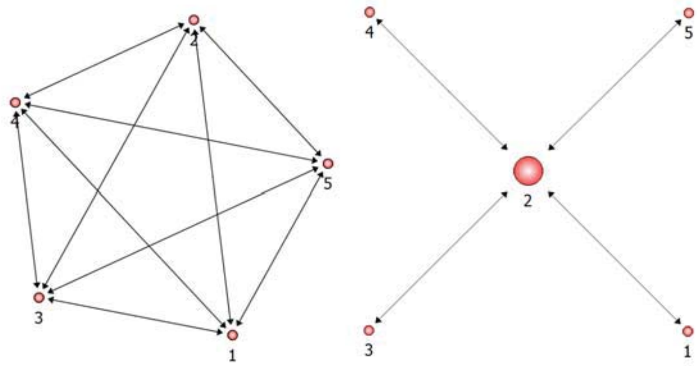
Communication Mode	Network Density
Formal	1
Written	0.4
Training	0.4
Toolbox Talks	1
Informal Discussions	0.4

It is shown that the group built a perfectly connected network for formal communications and toolbox talks, for which the network density is 1. However, a lower density at 0.4 was measured in the networks under all the other communications modes.

The member dominance of the safety communication networks of the pilot study group under different communication modes was analyzed using the measures of degree centrality and betweenness centrality. The safety communication networks of the pilot study group under different communication modes are shown in Figure 2. The values of the network density of the safety communication networks of the pilot study group under different communication modes are shown in Table 3.



(a) Formal Communications (b) Written communication (c) Training



(d) Toolbox Talks (e) Informal Discussion

Figure 2 Member Dominance in Safety Communication Networks of the Pilot Study Group

Table 3 Safety Communication Network Centrality of the Pilot Study Group

Group Member	Formal		Written		Training		Toolbox Talks		Informal Discussion	
	DC	BC	DC	BC	DC	BC	DC	BC	DC	BC
1	4	0	1	0	0.75	0	3	0	1	0
2	4	0	4	1	3	1	3	0	4	1
3	4	0	1	0	0.75	0	3	0	1	0
4	4	0	1	0	0.75	0	3	0	1	0
5	4	0	1	0	0.75	0	3	0	1	0

Note: DC: Degree Centrality; BC: Betweenness Centrality

It is shown that, under formal communication mode, the group is perfectly connected among members and thus there are no dominant actors for the group.

The results of the group's communication network under written communication mode indicate that a dominant actor is present in this network. The group member 2 (i.e. the field level manager) shows signs of a dominant member with a degree centrality of '4', '3' above the other group members. The betweenness centrality shows a similar result with the dominant group member having a betweenness centrality of '1' and all other members having '0'. This demonstrates a network where all communications must go through member 2. Therefore group member 2 is a dominant actor in the written safety communications.

The results also reveal a dominant actor in regards to the safety training communications. This is shown through the degree centrality, which has a standard deviation of '0.9' and a difference of '2.25'. This actor is further shown as dominant through the betweenness centrality of this member being 1 as opposed to the betweenness centrality of 0 held by the other group members. Therefore the member

2 of the group, i.e. the field level manager, is a dominant group member in the safety training communications.

Furthermore, similar to that under the formal communication mode, the group built a perfectly connected network for its toolbox talks on safety matters. This is due to the fact that all members are connected to each other. Additionally the results do not show any sign of a dominant member. This can be verified by a standard deviation in the degree centrality of '0'. Therefore there is no dominant member in the group for the toolbox talk communications on safety matters.

Finally, the results indicate that a dominant actor is present in the group in the safety communication network for informal communications. The group member 2 shows signs of a dominant member with a degree centrality of '4', '3' above the other group members. The Betweenness centrality shows a similar result with the dominant group member having a betweenness centrality of '1' and all other members having '0'. This is shown in the network by every group member needing to communicate through group member 2. Therefore group member 2 of the group is a dominant actor for the informal safety communications.

The group had a relatively low rate of estimated lost time injuries. The group was perfectly connected for formal communications and toolbox talks on safety matters. This may indicate that it is important to have a well-connected communication network for formal communications and toolbox talks in order to achieve better safety performance. Meanwhile, it may not be that important to have a perfectly connected communication network for written communication, training, and informal discussion. However, the results indicate that the fact that the networks that were built by the group for the members' communication on safety matters under the written communication, training, and informal discussion modes, although not perfectly connected, had a dominant member who communicated with all the other members might contribute to a high level of safety performance.

6 Conclusions

This paper reports on a pilot investigation that has been conducted into the relationships between a construction group's safety performance and their safety communication patterns in relation to interconnections and member dominance. It was found in the literature that the construction industry holds an exceptionally poor incidence rate and safety performance. It was also identified that safety communications that occur within the groups can have an effect on how safely those groups work. The current literature available showed that there are very few studies that have attempted to identify a relationship between safety performance of a construction group and their safety communications. The research on this specific area of construction safety was recognized to be theoretically valid and practically worthwhile to the construction industry and the academic community. A theoretical framework has been designed and displays two major constructs. These are the group's safety performance and their safety communication network patterns. These constructs were operationalized for the fieldwork of the pilot study. Data were acquired from a construction work group through a questionnaire survey. The data were then analyzed using social network analysis (SNA) software.

The findings from this pilot study show that the main identifiers of a group that has good safety performance might be its safety communication network patterns under formal communications and toolbox talks. For the safety communication networks under the other communication modes, such as written communication, training, and informal discussion, the indication may be that there need to be a dominant member who communicated with all the other members. Such findings, though requiring further verification, help to identify group communication network patterns that express good safety performances and may facilitate the industry in understanding how construction companies can form and manage their construction groups in order to reduce their incidence rates.

There are limitations in this pilot study mainly due to its explorative nature. Firstly, the sample is not large enough for statistical analyses and the findings may be biased. Secondly, the safety performance measure used could have been more in-depth to find more accurate data. Thirdly, the language barriers faced during surveys may have resulted in participants not fully understanding the questions. Lastly, cultural differences were not analyzed.

This pilot study shows the directions of further studies that can be taken in the future. It is recommended that this topic be explored in greater detail with a larger sample in the future. It is also recommended that similar studies be performed with altered focuses. These similar studies could look at the effectives or relationships of personal attributes in relation to safety performances and safety communication network patterns in highly multicultural countries with a highly multicultural workforce, such as Australia. Some of these attributes that are likely to influence safety communication networks are languages, age, gender, and ethnicity. Further, the input of other members within the organizations may be included to evaluate the influence of their input as well. The last suggested possible future direction would be to research the influence that inter-organizational safety communications within a project would have on the safety performances of groups.

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