Rita Yi Man Li *Editor*

Construction Safety: Economics and Informatics Perspectives

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Contents

How Does Social Exchange Theory, Perceived Organizational Support and Leader-Member Exchange Affect Construction Practitioners' Perception on Construction Safety? An Asymmetric Information Approach

Cho Kei Mak and Rita Yi Man Li

Abstract In this chapter, we conducted a survey on various stakeholders' perceptions of Social Exchange Theory, Perceived Organizational Support and Exchange's impact on construction safety. Many safety & environmental officers consider favourable job conditions the most crucial factor and then social rewards and morality. As per engineers, surveyors, and managers, group safety climate is the most critical sub-criteria in construction safety enhancement. Favourable job conditions ranked second. However, frontline workers considered leader-member exchange a critical factor different from safety officers & environmental officers. Engineers, surveyors and managers considered the essential criteria was perceived organisational support. The most crucial sub-criteria of "Front-line Workers" is group safety climate, followed by "Loyalty and Compliance of specific social goals".

Keywords Social exchange theory · Perceived organisational support and leader-member exchange · Construction safety · Asymmetric information · Hong Kong

1 Introduction

Constructions accidents on sites cause many injuries and mortality annually. Much money was spent on compensation each year. One leading cause of accidents was asymmetric information (Li & Poon, 2009) which suggested that one party has more

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or superior information than another (Xiang et al., 2012). Information asymmetry in construction project management lowered the effectiveness of decision making (Xiang et al., 2012). The risk arising from asymmetric information often happens due to poor decision-making (Xiang et al., 2012). Migrant workers who can only speak their dialects and cannot communicate well with other members on-site usually have higher accidental rates. (Debrah & Ofori, 2001).

An important issue of Asymmetric Information in site safety management is the principal-agent problem (Xiang et al., 2015). The safety performance of the construction projects could be enhanced if the client and project manager collaborate and share timely safety knowledge. Turner and Muller (2003) revealed that the owner has a principal-agent relationship with the contractor. One of the important issues of the principal-agent relationship is an incentive. The principal-agent problem happens due to conflicting interests between principals and agents. Thus, how to maximise the incentive mechanism is the recipe for the success of lowering the risks of safety in a construction project (Xiang et al., 2015). Dynamic project management based on the principal-agent model suggests that any changes in the principal participants' behaviour can alleviate the problem of information asymmetry in project safety management (Verma & Terpenny, 2005).

Huai and Wang (2004) focused on asymmetric information between the owner and the supervisor. In the bidding stage, the information advantages of supervisors included financial position, the number of employees and their quality, etc. In the real estate market, developers aim at higher profit margins with the help of information advantage (Xiang et al., 2015). In the contract implementation, the contractor may maximise his interests through improper and unethical means like reducing the investment in safety measures to lower the cost and get more profits. Owners would only consider the money they can earn but ignore the details of implementation procedures. If there are any accidents on the construction sites due to malpractice, however, they must bear the responsibility.

2 Social Exchange Theory (SET)

When individuals provide valued services to others, others need to respond and provide the desired services (Blau, 1964). Practitioners and organisations make decisions to maximise their benefits and minimise costs. Individuals expect reciprocal benefits when they engage in works like success and trust (Zhang & Jia, 2010). Hence, interpersonal interactions are a form of exchange where actors benefit from their actions (Shiau & Luo, 2012). Under the lens of social exchange, employees who perceive the organisational environment as a kind of support feel responsible for reciprocating the beneficial behaviours to their organisation.

Social Exchange Theory suggested that there are three significant forms of exchange in our society (a) rules and norms of exchange, (b) resources exchanged, and (c) relationships between the supervisors and subordinates (Cropanzano & Mitchell, 2005).

Reciprocity has been a critical concept considering social exchange theory which refers to the two-way relationship, mutually gratifying pattern of goods and services exchange (Gouldner, 1960). The social exchange theory and the reciprocity nature of organisations have been explained in the previous study (Eisenberger et al., 1990; Mearns et al., 2010).

After one party or person receives benefits, others feel that there is an obligation to compensate through effort (Mustapha et al., 2011). If the other reciprocates with a return of something like rewards, more rounds of exchanges will become possible (Zhang & Ng, 2012). The idea is like an n-round game theory where participants' behaviours in the first round will affect others later (Li, 2011; Li & Poon, 2011). Hence, Social Exchange Theory is characterised as the reciprocal relationship in which our actions will affect others (Zhang & Ng, 2012). Previous studies applied social exchange theory in safety climate research (Dejoy et al., 2010). The more the management commitment to workplace safety, the more enthusiastic the employees are to react when they perceive more significant social and organisational support for safety at work. Theoretical reviews and empirical findings have discovered the connection between safety climate perceptions and management commitment to safety. Social exchange theory applies economic and individual psychological principles to bilateral relationships form social exchange relationships with their organisations (Blau, 1964; Emerson, 1976; Homans, 1958; Zagenczyk et al., 2010).

The current study based on the social exchange theory signified that employees who work in a company with a favourable safety climate are more prone to perceive commitment to and better support safety and health protection (Huang et al., 2016). There is a higher chance for the employees on sites to reciprocate with safer behaviours to reduce accidents and injuries (Hofmann et al., 2003). Apart from greater motivation to work safely, a good safety climate can also lead to other positive outcomes, like higher job satisfaction, morality, and commitment to both organisation and society (Huang et al., 2016).

3 Cost-And-Benefit Relationship of Safety Climate

Social Exchange Theory explains reactions, either real or perceived, to be weighed against each other to predict a final action (Groth & Vogt, 2014). For example, human attitudes are determined by cost–benefit analysis. They would like to choose the alternative with higher gains to them. An increase in perceived benefits of adopting construction safety measures will increase the likelihood of adopting them.

Besides, according to the motivation theory, motivation is the incentive of an individual to act or not to act. From the perspective of psychobiological, perceptions of positive or negative phenomena stimulate an individual's behaviour (Moody & Pesut, 2006). It is the values that determine how humans behave in achieving their goals. On the other hand, incentive theory emphasises how external stimuli affect people (Weiten, 1992). While motivation stimulates independent variables by a person's favourite incentive (John Isaac Mwita, 2000), one's behaviour depends on his expectations of benefits and costs (Greer & Downey, 1982).

In this case, rewards and punishments are detrimental to construction safety behaviour for construction projects. Any external stimuli programmes, i.e. rewards or penalties, significantly affect the workers' safety on sites as they would calculate the gains and losses of whether to adopt the safety measures. According to social exchange theory, if the organisations offer benefits to improve construction safety measures and the benefits exceed the costs, construction workers will take safety actions. For example, if the benefits of training exceed costs, they will spend more time receiving training.

4 Relationships Between Safety Climate and Job Satisfaction, and Morality

Job satisfaction affects a specific job attitude of an individual (Judge & Kammeyer-Mueller, 2012). The relationship between safety climate perceptions and job satisfaction was assessed, and concluded that workers' perceptions of safety climate in their working environment positively stem from employees' job satisfaction (Morrow & Crum, 1998). It also revealed that individuals' safety climate perceptions directly relate to employee job satisfaction (Clarke, 2010). Positive safety climate perception would be a basic need for safety at work as it might result in employees' positive feelings toward their jobs.

Morality can also be beneficial to achieving a better safety climate on sites. This is in line with Maslow's theory, which suggested that satisfaction is built up from the bulwark of how well the job can satisfy the basic needs of the workers, such as safety (Maslow, 1954). Moreover, as mentioned before, employees with positive safety climate perceptions are prone to perceive support as a favourable treatment to their well-being. (Brambilla et al., 2013).

5 Relationships Between Safety Climate and Morality

Organisations' ethics affect various stakeholders, including the public, stockholders, other businesses, and employees. When it comes to contractual business, ethicists

emphasise moral legitimacy as a requirement of stakeholder relationships (Armenakis, Credo, Feild, & Young, 2010). Employees are obliged to the responsibility for safety at work; they adopt adequate safety measures even without legal requirements. Stakeholders have higher determination to enhance the safety environment on sites and put more resources into it, including buying more safety equipment.

If the workers have high morality, it is easier to spread the safety information from one individual to another, facilitating the reciprocity of safe behaviours at work. This may be more likely to create greater motivation to perform safely at work reciprocally (Michael et al., 2005; Huang et al., 2016).

6 Perceived Organizational Support (POS)

Fair resource distribution often imposes a significant impact on employees' POS. It depends on how much employees are convinced that the organisation cares about their well-being and treasures their contributions (Zacher & Winter, 2011). According to the theory of Perceived Organisational Support, employees act according to how the organisation values their well-being (DeConinck, 2010).

A high level of Perceived Organisational Support suggested that employees perceived that their organisation cares about their safety. In a high-risk working environment, where safety is a major concern, employees may have higher Perceived Organizational Support by assessing the organisation's effort to ensure employees' safety. Organisations will be more willing to spend more effort to ensure workers' health and safety in the workplace. This may reciprocally affect employees' perception of safety issues in the organisation (Li, 2015).

Perceived Organizational Support is based on the exchange relationship between employees and organisations (Eisenberger et al., 1986). Perceived Organizational Support is the employees' perception of how much the organisation values employees' contributions and cares about the employee's well-being, including safety issues (Eisenberger et al., 1986). With greater reward for meeting organisational goals, employees would be more likely to put effort into construction safety (Eisenberger et al., 1986). Beneficial treatments (e.g., safety communication, safety commitment, and favourable job conditions) received by employees are often associated with Perceived Organisational Support. They have higher job satisfaction and less withdrawal behaviour (Yu & Frenkel, 2013).

Considering construction safety, organisations need to support their employees (Hofmann & Morgeson, 1999). An employee's direct supervisor is often the individual who conveys these messages to them. It is of paramount importance for senior management to convey the support to line managers who can thus act as a conduit for support at the level of frontline employees. As in perceived organisational support literature, the management of a firm must use discretionary or voluntary actions to implement the goals towards a safe working environment with its employees (Kirk Ring, 2011).

When employees perceive the organisation's support and are committed to them (i.e., high POS), an implied responsibility is developed for reciprocity to benefit the organisation (Eisenberger et al., 1986, 1990). These benefits include engaging in organisational citizenship behaviours, which improves performance (Eisenberger et al., 1990).

7 Organisational Rewards

As mentioned above, rewards can be one of the incentives and motivations that encourage workers to work safely. The only difference between organisational rewards and rewards of Social Exchange Theory is that the organisations offer an organisational reward to their workers. At the same time, another one is the rewards from the society or government to promote safety climate in society (Moody & Pesut, 2006).

8 Safety Communication

POS is associated with safety-related communication as better organisation performance is ultimately beneficial to the organisation (Hofmann & Morgeson, 1999). Perceived organisational support was positively related to safety communication (Kirk Ring, 2011; Tucker et al., 2008). When employees perceive their organisations as supporting them, they are more willing to make suggestions with the intent of helping the organisation to improve the safe working environment because safety communication is one of the significant catalysts in creating a favourable safety climate (Kirk Ring, 2011). Human resource policies should be associated with an investment in employees—policies that should also foster higher POS—were more likely to engender positive employee behaviours (Tsui, Pearce, Porter, & Tripoli, 1997).

Various common communication problems regarding safety can be observed in organisations, despite informing management of potentially unproductive policies and practices (Tsui, Pearce, Porter, & Tripoli, 1997). Too much regular revisions on achieving organisational or departmental objectives can be another problem for construction project safety communication. If the organisation actively demonstrates its care for its workers, employees are likely to perceive that management emphasises safety concerns (Siew, 2015). The flourishing of safety concerns would provide more safety protection to the workforce.

9 Safety Commitment

Safety should not be limited to fulfilling the obliged laws and regulations; It shall also become a core virtue and a culture with a high sense of commitment from all levels of management within the organisation (Abudayyeh et al., 2006). Commitment is active instead of passive among all workers on sites (Amponsah-Tawaih & Adu, 2016). Management should also proactively assess the capacities of their workforce and assign appropriate workloads without overburdening the staff in avoidance of stamina or psychological problems. When employees perceive the organisational concern, they are more likely to feel that safety issues in construction projects are important (Kath, Marks, & Ranney, 2010). This can help increase their safety awareness and improve the organisation's safety climate.

10 Favourable Job Condition

Poor housekeeping is one of the significant construction culprits of accidents, while good housekeeping can lower the safety risks of construction projects (Hu, Rahmandad, Smith-Jackson, & Winchester, 2011). Favourable job condition is crucial to construction safety (Li, 2013; Poon, Tang, & Wong, 2008; Rozenfeld et al., 2010). In addition, excellent weather condition is also vital for lowering construction safety risk (Li, 2013). If the weather condition is terrible, organisations should stop site works and urge construction workers to find a shelter. Organisations should also be alerted to the instructions from the weather signals issued by the government promptly and take measures to protect the safety of workers on sites.

11 Fairness

Workers with positive fairness perceptions responded favourably to their organisations regarding safe work behaviour (Ayim Gyekye & Haybatollahi, 2014). If high-quality leader-member relations align with open and egalitarian communication, relationships between supervisors and subordinates would be strengthened. This can also raise their safety awareness and concerns (Hofmann & Morgeson, 1999).

Additionally, fair behaviours at the management level conduce to higher levels of job satisfaction which may enhance safety management policies compliance and lower accident rate (Ayim Gyekye & Haybatollahi, 2014). Conversely, workers' experiences of injustice treatment may be associated with poor safety climate. They will have lower job satisfaction after being mistreated and would be less committed to work safety, and an accident happens. Also, compliance with safety management policies would be necessary for construction workers who perceive fair treatment

and reciprocate safe behaviours. Equity can help workers restore personal feelings regarding social exchange relationships (Ayim Gyekye & Haybatollahi, 2014).

12 Leader-Member Exchange (LMX)

Leader-member exchange is defined as "an interpersonal relationship between supervisors and subordinates of a formal organisation" (Long, Li, & Ning, 2015). It measures the quality of interpersonal relationships between the immediate supervisor and employee (Trybou, Gemmel, Pauwels, Henninck, & Clays, 2014). The organisation agents' historical decisions always determine their relationships. A high-quality Leader-Member Exchange simultaneously meets the employees' needs to comply with specific social goals and group safety climate, facilitating positive role engagement (Li & Liao, 2014). The higher the degree of leader-member exchange, the better the performance of both subordinates and supervisors and the loyalty of promising employees.

In high risk working environments, especially in the construction industry, safety record is usually used as an indicator to evaluate supervisors' performance. Employees' reciprocal safety-related positive attitudes and behaviours would help supervisors maintain a good safety record. In such a risky working environment, a high-quality Leader-Member Exchange will lead supervisors to be concerned for workers' safety. It also prioritises safety over other factors such as production and cost. Supervisors' safety concerns can motivate employees to have improved safety performance (Li, 2015).

Organisations should encourage good and sufficient exchange relationships between supervisors and subordinates. Positive exchange relationships tend to encourage members to raise their safety concerns which can lead to the identification and implementation of safety programs in the long run (Hofmann & Morgeson, 1999).

The concept of the Leader-member exchange relationship stems from amicability between the leader (supervisor) and his follower (employees). To apply the concept of exchange related to the relationship between supervisors and employees, both parties must offer something valuable to each other (Ahmed et al., 2011). For instance, under the circumstances of safety issues on construction sites, employees offer safe performance and behaviour in which they are given a reward in return (Guo et al., 2015).

When organisations value and care for their workers, employees' safety concerns are raised once they perceive proactive management support. In this case, supervisors should establish a positive exchange relationship among employees to improve job and safety performance (Michael et al., 2006). So, it can be signified that the leader-member exchange is the relationship applied in an organisation can provide positive returns for the institution.

13 Relationship

Organisations are encouraged to deploy resources to enhance the dyadic relationships between employees and supervisors for construction safety instead of only applying resources, such as time, money, and human resources, to enhance safety policies and procedures (Kath, Marks, & Ranney, 2010). In addition, it would be beneficial for organisations to hold some relationship-building activities or campaigns to enhance the relationship between the employers and employees (Conchie et al., 2013). Doing so may facilitate safety message communication, and the organisation can become a safer place to work. Moreover, enhancing the safety climate is conducive to the construction companies, which has a significant impact on the safety performance (Wu et al., 2011; Martínez-Córcoles et al., 2013; Gyekye & Haybatollahi, 2014).

14 Historical Decisions

Historical delineation of relationships and historical decision legitimacy play an essential role in the relationship between supervisors and their subordinates (Gordon, 2008). By applying antecedent forms of power, including historical delineation of relationships and historical decision legitimacy, the leaders can continuously exert their influence and legitimacy on the decision making (Bolden, 2011).

It can urge the workers on sites to listen to their instructions and orders effectively and efficiently for the safety issues. If the supervisors have made a good track record, the governance of a construction organisation will be improved as their workers would listen more to the safety orders and instructions from their supervisors.

15 Safety Climate

Whether a safety climate is in a favourable nature is based on the perceptions of management's actions and an indication of employee value (Kirk Ring, 2011). Safety climate and perceived organisational support rely on appropriate management actions, adequate training of employees, and legitimate concern for the value and well-being of employees. Each of these leads to reciprocal behaviours such as organisational commitment and more effective work habits (Kirk Ring, 2011).

Safety climate cannot just rely on a single institution or organisation but have to promote the safety message sharing throughout the whole industry. The mediating role of safety culture in construction sites is important in the relationships between different stakeholders' safety issues (Wu, Wang, Zou, & Fang, 2016). Compared with individual factors, cultural factors tend to have more immense power to spread and penetrate throughout the organisation, especially for construction projects with

high labour mobility. After providing a positive climate of safety, employees will feel more comfortable communicating safety-related issues with their supervisors, which will improve safety communication within the organisation (Kath, Marks, & Ranney, 2010). Thus, safety culture development should be a critical issue for managers to improve safety performance.

16 Compliance

Safety climate is positively related to safety compliance as that can decrease the number of injuries on sites (Kath, Marks, & Ranney, 2010). What makes the employees comply with the instructions and the legal requirement on the safety measures requires skills and techniques that mainly originate from the relationship between supervisors and employees. When their relationship improves, it is easier for them to perceive the safety instructions and rules on sites as an order (Kath, Marks, & Ranney, 2010).

Some safety management practices influence safety compliance and participation via the mediating effect of workers' safety knowledge and motivation. Safety compliance and participation partially mediate the effect of safety climate (Li, 2015).

17 Loyalty

Loyalty measures the degree of loyalty from the dyad party (Olsson, Hemlin, & Pousette, 2012). Loyalty involves faithfulness to the individual that is generally consistent under different situations (Olsson, Hemlin, & Pousette, 2012). The more support an employee gives to a supervisor, the more she or he will become part of the leader's "inner circle". These adherent support their leader, and it is the loyalty that the leader seeks to cultivate safety consensus. To reward this support, the leader favours the subordinates in the form of recognition when it comes to construction safety issues. The higher the loyalty, the higher the chance the employees perceive safety instructions and rules as a necessity in which they do not want to have any accidents that will hamper the interests of the supervisors and organisations.

18 Hypotheses

According to the literature, we now propose the following two hypotheses:

H1: Social exchange, POS and LMX have different levels of importance regarding safety performance.

It is assumed that different people have different views regarding construction safety issues with different extents of willingness. Once their willingness is different from the others, their perception of safety issues on sites may be different. For example, someone likes money more may like social and organisational awards more.

H2: Asymmetric information exists so that all the workers, managerial staff, and safety officers have different degrees of perceptions regarding H1.

It is assumed that construction employees have asymmetric information due to their various backgrounds, like educational background, working experience on sites, job duties, personality, etc.

19 Research Method

19.1 AHP

The quality of construction safety systems is a function of many factors. Management of those systems thus requires a holistic approach and a multi-criteria analysis. In addition, the AHP method is used to analyse and quantify the risk assessment of the construction sites.

19.2 Analytic Hierarchy Process

Analytic hierarchy process (AHP) is a structured multi-attribute decision method (Saaty, 1990). This method provides group decision making through consensus of the individual judgments to reduce bias in the process of decision making (Aminbakhsh, Gunduz, & Sonmez, 2013). The main advantage of AHP is to check and reduce the inconsistency of interviewees' judgments.

AHP involves assessing scales that are shown in Table 1. AHP uses scales of values from pairwise comparisons that are suitable for multi-objective, multi-criterion, and multi-actor decisions with any number of alternatives. Therefore, it can model difficult situations to measure objectively (e.g., modelling risk and uncertainty). AHP is comprised of three main principles: decomposition of the structure, comparison of alternatives, and synthesis of priorities. Decomposing a decision problem into its constituent parts facilitates building criteria hierarchies to determine the importance of each criterion.

A systematic weighing process based on facts and shared values is a prerequisite for the transparency and legitimacy for measuring the relative importance of indicators affecting construction safety. Accordingly, the AHP, which was developed by Saaty (1977), was chosen for this study to generate weightings of the attribute. Among the major attractions of the AHP, its use of pairwise comparisons is the

Table 1 AHP scale for combinations

Saaty scale	Definition	Verbal explanation
1	Equally important	Two elements contribute equally to the issue
3	Weakly important	Low significance of one element compared to another
5	The Fairly important	Substantial significance of one element compared to another
7	Strongly important	Confirmed dominance of one element over another
9	Absolutely important	The absolute dominance of one element over another
2	The intermittent values between two adjacent scales	Intermediate values between two neighbouring levels
4		
6		
8		

best (Yau, 2006). This form of data input is generally deemed straightforward and convenient. Also, it checks the internal inconsistencies.

Data for determining attribute weights is often unknown in absolute values (Triantaphyllou et al., 1997). The importance of an indicator towards a particular objective is always qualitative. Information about questions in assessing attribute weights is complicated, if not impossible, to quantify correctly. In AHP, there is no need to accurately estimate the pertinent data by using pairwise comparison (Triantaphyllou et al., 1997).

Furthermore, pairwise comparisons help decision-makers avoid being overwhelmed with a large amount of information that must be processed per unit time. To focus on comparing two attributes each time, decisions can be made without extraneous influences (Yau, 2006). So, AHP is helpful when there are many indicators. Moreover, AHP allows checking of the respondent's results for any internal consistency, which is essential for the identification of illogical responses of the respondents.

20 Computation Details of AHP

AHP can help decision-makers compare the importance of the factors relatively quantitatively. The following section details the computations of factor weights and consistency ratios using the AHP. Without the loss of generality, the weights of n factors will be determined. The weight of each factor which is non-negative $f_i = (i = 1, 2, 3, \ldots, n)$ is denoted by w_i, and the set of weights of the n factors is given by w where:

$$\mathrm{w} = \begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ \cdot \\ \cdot \\ \cdot \\ r_n \end{pmatrix} \tag{1}$$

The relative importance of factor f_i compared to $f_i = (i = 1, 2, 3, \ldots, n)$ is measured by the ratio $\frac{r_i}{r_j}$. The weight of all factors is the total sum to unity. Saaty (1977) suggested that the proper eigenvector method is used to assess the factor weights in a standard AHP approach. This method was initiated with a combination of all n possible pairwise column vectors into a comparison matrix Z as follows:

$$Z = \begin{pmatrix} \frac{r_1}{r_1} & \frac{r_1}{r_2} & \frac{r_1}{r_3} & \cdots & \frac{r_1}{r_n} \\ \frac{r_2}{r_1} & \frac{r_2}{r_2} & \frac{r_2}{r_3} & \cdots & \frac{r_2}{r_n} \\ \frac{r_3}{r_1} & \frac{r_3}{r_2} & \frac{r_3}{r_3} & \cdots & \frac{r_3}{r_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{r_n}{r_1} & \frac{r_n}{r_2} & \frac{r_n}{r_3} & \cdots & \frac{r_n}{r_n} \end{pmatrix} \tag{2}$$

The upper right and the lower left triangle blocks are reciprocal, and the diagonal elements in A are equal to unity. Multiplication of Z by w yields:

$$Zw = \begin{pmatrix} \frac{r_1}{r_1} & \frac{r_1}{r_2} & \frac{r_1}{r_3} & \cdots & \frac{r_1}{r_n} \\ \frac{r_2}{r_1} & \frac{r_2}{r_2} & \frac{r_2}{r_3} & \cdots & \frac{r_2}{r_n} \\ \frac{r_3}{r_1} & \frac{r_3}{r_2} & \frac{r_3}{r_3} & \cdots & \frac{r_3}{r_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{r_n}{r_1} & \frac{r_n}{r_2} & \frac{r_n}{r_3} & \cdots & \frac{r_n}{r_n} \end{pmatrix} \begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ \cdot \\ \cdot \\ \cdot \\ r_n \end{pmatrix} = \lambda W \tag{3}$$

where w is the right eigenvector of A with an associated eigenvalue λ. λ, in the consistent case, is the only non-zero eigenvalue of A. Nonetheless, inconsistency in A occurs once a change is made to the ratio $\frac{r_i}{r_j}$. In this situation, multiple eigenvectors and eigenvalues coexist. The degree of inconsistency remains negligible if the change to the ratio $\frac{r_i}{r_j}$ is tiny, which leads to the principal (or largest) eigenvalue λ_{max} close to λ. In this case, the principal right eigenvector is still a good approximation of w which

means that the eigenvector is in a perfectly consistent situation. Thus, with Z', which is an expert's estimate of Z, Saaty (1977) proposed to find out the corresponding weight vector w' of the equation:

$$Z' w' = \lambda_{\max} w' \tag{4}$$

It may be shown that $\lambda_{\max} \geq \lambda$. The deviation of the principal eigenvalue $\lambda_{\max}$ from λ is used to define a consistency ratio (CR):

$$CR = \frac{CI}{RI} \tag{5}$$

where CI is the consistency index that is defined by:

$$CI = \frac{\lambda_{\max} - \lambda}{\lambda - 1} \tag{6}$$

where n is the size of the judgement matrix.

It is challenging to meet the consistency of varying degrees, so it is necessary to introduce consistent indicators RI, the random index values, as shown in Fig. 1. In general, CR smaller than 0.1 is considered acceptable because this is close to the situation $\lambda_{max} = \lambda$ when the comparison matri x Z is consistent (Saaty, 1977). If $\frac{CI}{RI}$ <0.1, the consistency of this matrix cannot be accepted, and the judgment matrix should be re-established.

Table 2 illustrates the process of obtaining the AHP's weighting of the attributes. To have a more reliable result, it is required to check the respondent's results for internal consistency, which is essential for identifying and minimising any illogical responses of the respondents.

Determinants for the construction safety behaviour can be determined by three major criteria, which are reciprocal benefits (Social Exchange Theory), Perceived Organizational Support and relationship between supervisors and subordinates (Leader-Member Exchange) (Li, 2015). The key occupational safety indicators are identified as sub-criteria under each criterion (like rewards, fairness, loyalty and so on), shown in Fig. 2.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Fig. 1 Figure showing RI index (Saaty, 1977)

Table 2 The procedures of the AHP data collection process (Source: adapted from Yau, 2006)

Step	Procedure
Step 1	Literature for the components of the hierarchy of AHP is collected
Step 2	The hierarchy of AHP is constructed
Step 3	The questionnaire of the study is designed
Step 4	The questionnaires are sent to the respondents and then collected
Step 5	A pairwise comparison is constructed. The respondent is allowed to revise his/her response either following the suggestion of the computer package or filling in the questionnaire again
Step 6	If the internal consistency ratio is still not below 0.1, the respondent can follow Steps 4 and 5 again for further revision. The process continues until the respondent rejects making any further changes
Step 7	The revision is keyed into a computer, and each indicator's weighting is obtained

21 Data Description

To collect the data required for AHP and social network analysis, questionnaires and interviews with construction employees, including safety officers, foremen, general managers, committee members of the Construction Labor Union and so on have been conducted in eleven construction sites (Mak, 2017).

In the following analysis, all respondents are divided into four groups with similar nature of work. The first group is safety officers and environmental officers. There may not be any safety officers, but only safety and environmental officers in a small construction site, so both job titles are combined in the same group for analysis. The second one is engineers and surveyors whose safety is part of their work but not their day-to-day handling task. The third one is the managers, who were the middle or top management of the construction companies who have a significant role in the work's supervision, including plans and commitments to overall construction safety (Mak, 2017) (Fig. 3).

This study included 54 valid questionnaires for the AHP analysis. The respondents included safety officers, environmental officers, surveyors, engineers, general managers, clerks of work, site agents, a labour union representative, foremen, and construction workers. Among all the questionnaire respondents, 19 were safety officers and environmental officers, 18 were engineers and surveyors, 8 were managers and 9 were frontline Workers (Mak, 2017).

Since different sets of weights were determined using the AHP for individual experts, there was a need to aggregate them into a unified set of weights. All individual weightings are the same as every construction employee can play an important role in providing a safe working environment, and their weighting should be equal. Every respondent's opinion is equally important to the analysis as everyone can be a major pillar in providing a safe working environment on sites (Mak, 2017).

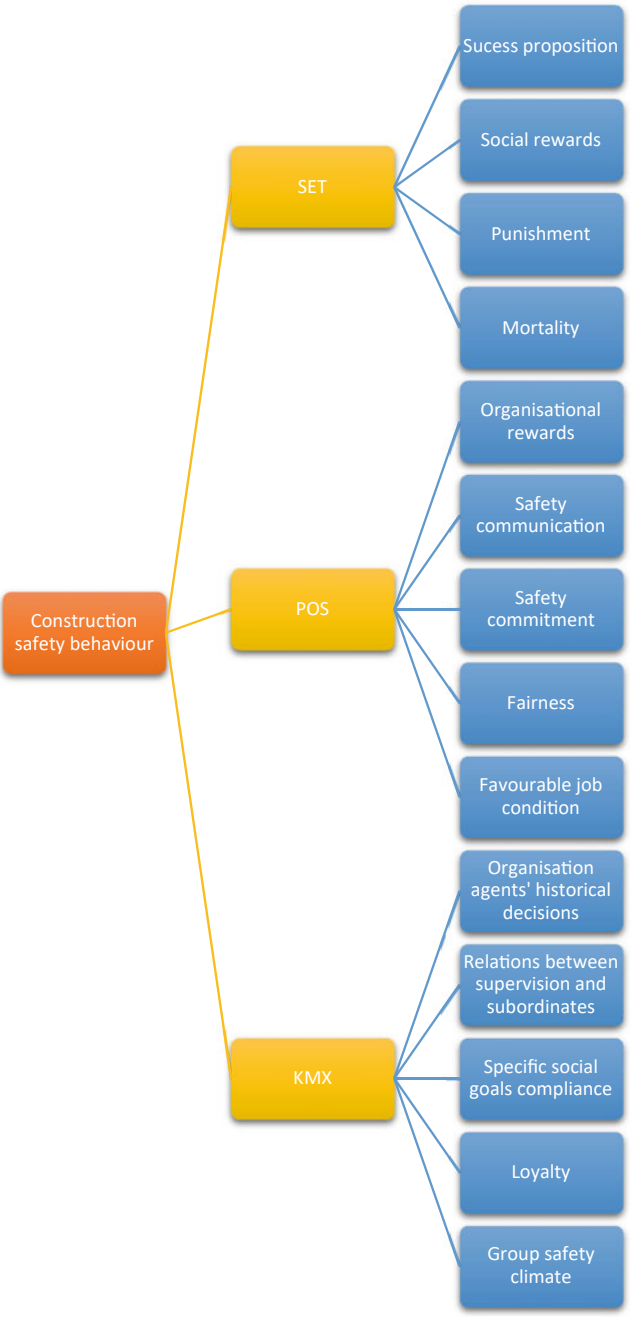

Fig. 2 Hierarchy of construction safety (Mak, 2017)

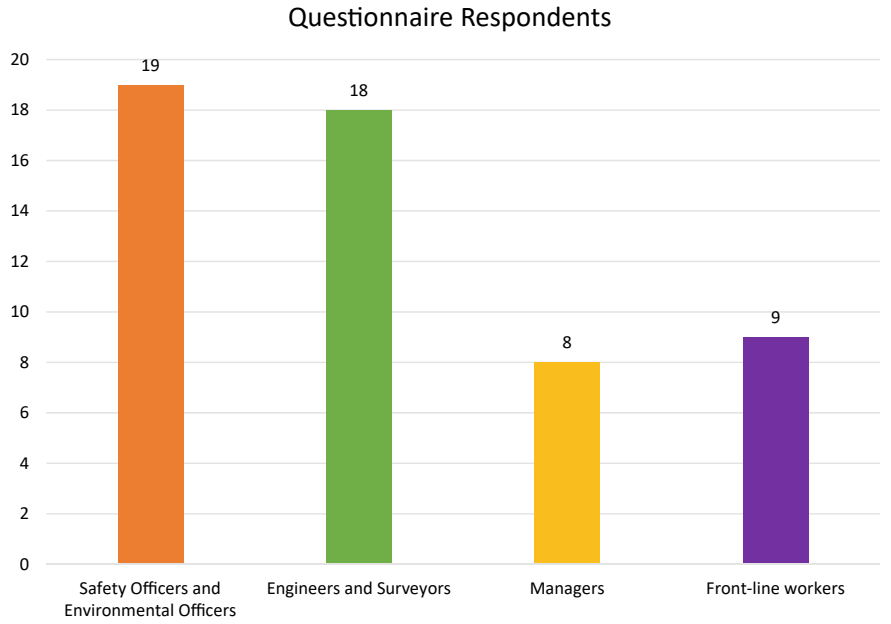

Fig. 3 Composition of the questionnaire respondents in the AHP analysis

Tables 3, 4, 5, 6 and 7 record the research results. The most important criteria affecting construction safety among safety officers & environmental officers, engineers and surveyors and managers were perceived organisational support, which were 42.34, 37.75, and 38.63%, respectively, in their hierarchy.

Among all sub-criteria of safety officers & environmental officers, a favourable job condition was as the most crucial, amounting to 11.77%. It is followed by Social Rewards (10.25%) and Morality (9.51%).

As per engineers and surveyors (13.97%) and managers (13.48%), group safety climate was the most crucial sub-criteria for improving construction safety. It was followed by a favourable job condition which attributed 11.63% among engineers and surveyors and managers (12.99%) respectively.

However, frontline workers considered the most important criteria would be leader-member exchange with 43.9%, which was different from safety officers and environmental officers, engineers and surveyors and managers who ranked Perceived Organisational Support as the most important. The most crucial sub-criteria of front-line workers was group safety climate (12.38%) followed by loyalty (8.94%), and compliance with specific social goals (8.56%).

Among all criteria affecting construction safety, from the opinion of all respondents, Perceived Organizational Support was recognised as the most crucial aspect, amounting to 38.22%. It was followed by Leader-member exchange (32.77%) and Perceived Organisational Support (29.02%).

Concerning all respondents' opinions, the most critical sub-criteria are Group Safety Climate with 11.77%, followed by Favorable job condition (10.77%), Social Rewards (8.93%), mortality (8.40%) and fairness (8.02%). The least important sub-criteria are organisation agents' historical decisions (3.71%), punishment (4.57%) and loyalty (4.62%). Combined with the results discussed above, this finding indicated the utmost importance of the configurations and conditions in alleviating construction safety problems. Table 8 summarises the weights of all interview participants.

An ordinary correlation test was carried out to investigate the relationship among the sets of rankings given by different professionals. The results of the test are presented in Table 8 in matrix form. Table 9 summarises the weightings of the attributes obtained from respondents of different construction employees.

From Table 9, "Safety Officers and Environmental Officers" and all respondents has the highest correlation (0.9978), which was statistically significant at the 5% level. "Safety Officers and Environmental Officers" and "Engineers and Surveyors" was second (0.9017), also statistically significant at the 5% level.

On the other hand, there seems to be a significant difference of views towards the relative importance of construction safety criteria and sub-criteria importance between "Frontline workers" and all respondents (0.1861) and "Engineers and

Table 3 AHP results in social exchange, perceived organization support and leader membership exchange (Mak, 2017)

Criteria	Sub-criteria	Weighting (%)	Ranking
Social exchange theory (32.86%)	Success proposition	7.8572	6
	Social rewards	10.2530	2
	Punishment	5.2413	10
	Morality	9.5088	3
Perceived organisation support (42.34%)	Organisational rewards	7.0193	9
	Safety communication	7.6718	7
	Safety commitment	8.2153	5
	Favourable job condition	11.7672	1
	Fairness	7.6658	8
Leader-member exchange (24.80%)	Organisation agents' historical decisions	3.7069	13
	Relationship between supervisors and subordinates	4.7354	11
	Compliance with specific social goals	4.6810	12
	Group safety climate	8.3249	4
	Loyalty	3.3516	14

Table 4 Summary of the weights from the "safety officers and environmental officers" (Mak, 2017)

Criteria	Sub-criteria	Weighting (%)	Ranking
Social exchange theory (25.68%)	Success Proposition	6.2282	9
	Social rewards	9.3767	3
	Punishment	3.7827	13
	Morality	6.2889	7
Perceived organisation support (37.75%)	Organisational rewards	6.1400	10
	Safety communication	5.4784	11
	Safety commitment	6.2684	8
	Favourable job condition	11.6314	2
	Fairness	8.2318	5
Leader-member exchange (36.573%)	Organisation agents' historical decisions	2.5668	14
	Relationship between supervisors and subordinates	6.7843	6
	Compliance with specific social goals	8.6285	4
	Group safety climate	13.9716	1
	Loyalty	4.6214	12

Table 5 Engineers and surveyors' perceptions (Mak, 2017)

Criteria	Sub-criteria	Weighting (%)	Ranking
Social exchange theory (31.235%)	Success proposition	9.5997	4
	Social rewards	6.0842	8
	Punishment	3.7127	12
	Morality	11.8385	3
Perceived organisation support (38.6313%)	Organisational rewards	4.6894	10
	Safety communication	6.8126	6
	Safety commitment	5.2722	9
	Favourable job condition	12.9878	2
	Fairness	8.8678	5
Leader-member exchange (30.1288%)	Organisation agents' historical decisions	2.2096	14
	Relationship between supervisors and subordinates	4.4820	11
	Compliance with specific social goals	6.3888	7
	Group safety climate	13.4811	1
	Loyalty	3.5680	13

Table 6 Summary of the weights from "Managers"

Criteria	Sub-criteria	Weighting (%)	Ranking
Social exchange theory (25.97%)	Success proposition	5.4434	12
	Social Rewards	7.2244	5
	Punishment	5.4284	13
	Morality	7.8783	4
Perceived organisation support (30.12%)	Organisational rewards	6.3252	9
	Safety communication	5.4225	14
	Safety commitment	5.6552	10
	Favourable job condition	5.6321	11
	Fairness	7.0880	7
Leader-member exchange (43.90%)	Organisation agents' historical decisions	7.1569	6
	Relationship between supervisors and subordinates	6.8658	8
	Compliance of specific social goals	8.5591	3
	Group safety climate	12.3761	1
	Loyalty	8.9381	2

Table 7 Summary of the weights from "Frontline workers" (Mak, 2017)

Criteria	Sub-criteria	Weighting (%)	Ranking
Social exchange theory (29.02%)	Success proposition	7.1201	6
	Social rewards	8.9306	3
	Punishment	4.5694	13
	Morality	8.3953	4
Perceived organisation support (38.22%)	Organisational rewards	6.3238	10
	Safety communication	6.4139	9
	Safety commitment	6.6863	8
	Favourable job condition	10.7748	2
	Fairness	8.0165	5
Leader-member exchange (32.7666%)	Organisation agents' historical decisions	3.7101	14
	Relationship between supervisors and subordinates	5.8088	11
	Compliance of specific social goals	6.8632	7
	Group safety climate	11.7683	1
	Loyalty	4.6163	12

Table 8 Summary of the weights of all interview respondents

Criteria	SO&EO (%)	Engineers and surveyors (%)	Managers (%)	Frontline workers (%)	Overall (%)
SET	32.86	25.68	31.24	25.97	29.02
POS	42.34	37.75	38.63	30.12	38.22
LMX	24.80	36.57	30.13	43.90	32.77
Sub-criteria					
Success proposition	7.86	6.23	9.60	5.44	7.12
Social rewards	10.25	9.38	6.08	7.22	8.93
Punishment	5.24	3.78	3.71	5.43	4.57
Morality	9.51	6.29	11.84	7.88	8.40
Organisational rewards	7.02	6.14	4.69	6.33	6.32
Safety communication	7.67	5.48	6.81	5.42	6.41
Safety commitment	8.22	6.27	5.27	5.66	6.69
Favorable job condition	11.77	11.63	12.99	5.63	10.77
Fairness	7.67	8.23	8.87	7.09	8.02
Organisation agents' historical decisions	3.71	2.57	2.21	7.16	3.71
Relationship between supervisors and subordinates	4.74	6.78	4.48	6.87	5.81
Compliance of specific social goals	4.68	8.63	6.39	8.56	6.86
Group safety climate	8.32	13.97	13.48	12.38	11.77
Loyalty	3.35	4.62	3.57	8.94	4.62

surveyors" and "Managers" (0.1945). The reason behind is their difference in professional backgrounds and job duties, so their views of the relative importance of each safety attribute can be different.

This book chapter's results indicated that Social exchange Theory, Perceived Organizational Support and Leader-Member Exchange have different levels of importance on safety performance.

Different types of construction employees have different perceptions of the relative importance of site safety attributes. The perceptions of the relative importance of

Table 9 Matrix shows correlations among different construction employees

	SO&EO	Engineers and surveyors	Frontline workers	Managers	Overall
SO&EO	1				
Engineers and surveyors	0.9017**	1			
Frontline workers	0.8192**	0.5806	1		
Managers	0.5497	0.1945	0.5017	1	
Overall	0.9978**	0.8915**	0.1861	0.5912	1

Note **significant at the 5% level

building safety attributes may differ among employees with different backgrounds. Also, due to their differences in job duties, respondents have different degrees of information received, which also causes different perceptions.

For example, frontline workers may not know about the newly imposed safety policies, but probably a safety officer knows more about them. Asymmetric information leads to the difference in the perception on safety issues. Also, asymmetric information exists due to differences in educational background and experiences.

22 Conclusion

This book chapter researched various stakeholders in construction sites regarding their perceptions of the impact on construction safety behaviour. AHP analysis proved that respondents had different perceptions of Social Exchange Theory, Perceived Organizational Support, and Leader-Member Exchange's impact on construction safety. Safety officers and environmental officers, engineers and surveyors, and managers considered Perceived Organizational Support the most important ones to alleviate construction safety risk.

Group safety climate was considered the most crucial sub-criteria for improving construction safety among engineers and surveyors and "Managers". However, frontline workers considered the most important criteria was a Leader-member exchange. Thus, the differences evidenced the impact of asymmetric information on the perceived most critical factors affecting construction safety on sites.

In practice, when construction safety officers implement relevant safety rules on sites, they may have to consider the workers' perceptions, who may have a higher chance of coming across construction safety. Academically speaking, this book chapter opens a new direction for asymmetric information research on the construction industry. For example, we may study ethnic minorities' perception of safety when we compare the local construction workers. In the case of policy makers,

they have to consider individual groups' differences when they wish to implement new safety rules or even safety laws, as compliance is related to people's perceptions.

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An Appraisal of Drivers to Efficient Occupational Health and Safety Performance Management for Small-Scale Contractors in Zambia

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Abstract There is need to develop occupational health and safety drivers that would improve occupational health and safety performance management, for small-scale contractors. This need is also significant for project stakeholders such as government agencies, clients, professionals and financiers. According to studies, these stakeholders in Zambia devote less attention to have drivers and indicators for occupational health and safety performance. After a thorough review of literature on the drivers to improved occupational health and safety performance management, the Delphi study was adopted as a methodology to establish consensus of the drivers among professionals. A structured 10-point Likert scale of influence questionnaire was developed as a measuring instrument. The questionnaire was administered to professionals with adequate experience and knowledge on occupational health and safety performance management in the electricity industry. Findings indicated that management strategy, finance, employee involvement, hazard identification and management, training and promotion, actions for improvement, employee wellbeing and government provision of occupational health and safety services are crucial to achieving goals and objectives for efficient occupational health and safety performance management. The developed drivers were found to be workable, adaptable, and capable of improving health and safety performance management for small-scale contractors and stakeholders in Zambia.

Keywords Drivers · Occupational health and safety · Performance management · Small-scale contractors · Zambia

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1 Introduction

At the global level, the poor performance of occupational health and safety (OH&S) has significantly come to the fore in recent years and has been ascribed to failure by small scale contractors (SSCs) in improving OH&S during the implementation of projects (Carrillo, 2010; Mwanaumo & Mambwe, 2019). The need to improve OH&S performance management has been highly informed by the International Labour Organisation (ILO, 2019) and Occupational Safety and Health Association (OSHA, 2017). The ILO (2019) noted that about 4% of the global gross domestic product is burdened by OH&S injuries, accidents, and diseases. In 2019, the International Labour Organisation (ILO, 2019) reported that an increase of about 374 million employees experience non-fatal accidents, while 2.78 million employees died in 2019 due to occupational accidents and workplace distress, while about 6,300 employees die globally daily. This accounts for 1.5% of healthy lost life due to workplace injuries and diseases (Fuller, 2019). About 6.9% and 13.7% fatalities out of 100,000 employees in Europe and the United States of America respectively, were reported, while in Africa, work fatalities were reported to be 18.6% for every 100,000 employees, of which the most highly affected with fatalities are SSCs (ILO, 2019). Developing countries in Africa have also not been spared from the rise in OH&S accidents, injuries, and fatalities due to poor OH&S performance. In South Africa, about 230 fatal accidents, 780 non-fatal accidents, and 12 major injuries recorded by the Department of Labour in 2019.

The electricity industry is very significant in the development of economies despite the increase in the number of injuries related to work, accidents, diseases, and fatalities that have been on the rise in the last decade. The industry is very complex, dangerous and any incident can be catastrophic and challenging. In the United States of America, in 2018 the industry recorded 18% increase from 2017, of fatalities at workplaces in the electricity industry, with 849 electrical fatalities coming from construction activities (Electricity Safety Foundation International, 2020). The Electricity Supply and Investment (ESI, 2018) reported that work-related fatalities of over 59,000 with 4 million non-fatal accidents in Africa were recorded just in 2018 alone.

Like any other developing country, Zambia has not been spared with the rise in OH&S accidents, injuries and fatalities at workplaces, especially at projects in the electricity industry. The poor OH&S performance in the electricity industry has been attributed to the inflow of new players joining the industry, such as SSCs that have been allowed to take part in the infrastructural development of the electricity industry to ensure that the increasing electricity demand are met (Energy Regulation Board, 2018). Additionally, the Worker's Compensation Fund Control Board (WCFCB, 2020) indicate that electrical-related fatality rates are about 4% of all incidents in 2019. The Energy Regulation Board (2018) key performance indicators show over nine fatalities were recorded in 2018 under the electricity subsector driven by contractors' negligence on-site, while 1,200 accidents were recorded in the same year during construction and operation phases of projects in the industry (WCFCB, 2020). It was further affirmed by the National Council for Construction (NCC, 2020)

that the majority of the SSCs (NCC Grade 4, 5 and 6) operate at low capacity due to difficulties in securing continuous contracts, engaged in the construction of projects in the electricity sector, and are in most cases non-compliant to the requirements of OH&S regulations at workplaces.

Mambwe et al. (2021) and Grant (2010) stated that poor work conditions for employees are common in small-scale contracting firms, while OH&S best practices are not adopted, such as the provision of tools, personal protective equipment (PPE), and reporting of OH&S incidents. Small-scale contractors perceive aspects of OH&S, including its implementation as a cost that impacts on the profits of the firms, and thus fail to provide fundamental requirements to employees such as PPE, health care access, and training in OH&S management (Mwanaumo & Mambwe, 2019; NCC, 2018). Hence, the need to appraise drivers that can be used as strategies specific to the industry to improve the performance of OH&S. Additionally, there is limited research on drivers and indicators tied to OH&S performance management for SSCs at projects in Zambia's electricity industry. In order to enhance OH&S performance management at projects carried out in the electricity industry, identifying drivers and indicators as a means to lowering fatalities, accidents, and injuries, it was significant. Hence, the study's objective was to appraise drivers and indicators that lead to improved OH&S performance management at projects by SSCs.

2 Drivers to Efficient Occupational Health and Safety Performance Management

Literature indicate that no agreed and standard measures or drivers of OH&S performance management exist for improvement or efficient implementation. The Occupational Health and Safety Committee (OHSC, 2017) highlights that indicators can be categorised to echo the elements of the workplace systems. The Committee further mentioned that drivers should be designed to exhibit high levels of OH&S performance management (OHSC, 2017). Further, SSCs should adopt drivers related to their operation and appropriate for OH&S performance (Wang et al., 2016; Windapo & Oladapo, 2012). Fernandez-Muniz et al. (2009) highlighted the lack of consensus on the drivers for OH&S performance management, while Wachter and Yorio (2014) further noted that OH&S performance management drivers for improvement should relate to the overall goals and objectives of an organisation or a project. Therefore, after a rigorous literature review, eight drivers were appraised in this study, including management strategy, finance, employee involvement, hazard identification management and review, training and promotion, and actions for continuous improvement. A summary of the drivers and their indicator measures from literature are presented in Table 1. Also, gaps from literature indicate that there is need to adopt employee wellbeing and government provision of occupational health and safety services as significant gaps in OH&S performance management.

2.1 Management Strategy

According to Mwanaumo and Mambwe (2019) management strategy depends largely on the levels of commitment by management to improving OH&S performance at the workplace. It was further described by Manu et al. (2018), Gunduz and Laitinen (2017) and Robson et al. (2007) as a bunch of actions and plans that are formulated by management to improve the firm's performance of OH&S through knowledge and analysis. However, ILO occupational health and safety model for 2001, management strategy allows for the integration of various drivers that inform OH&S policy and objectives so the objects of the firm on OH&S are met. Further, Mambwe et al. (2021) highlight that management strategy should identify approaches or plans that can be used to achieve improved performance in OH&S and therefore attain competitive advantage for their organisation. Therefore, it can be said that systematic and effective structures are vital as they are intended to reduce injuries, accidents, ill-health, and damage to property (Fernández-Muñiz et al., 2009; Fruhen et al., 2014). Hence, the main purpose of management strategy is to reduce or eliminate work-related injury, accidents, and disease, through the provision of a policy, commitment, accountability, integration of OH&S activities with management functions, safe work procedures, permit to work, emergency preparedness plans as indicted in Table 1.

2.2 Finance

Organisations including small contracting firms, should realise how important and beneficial investing in OH&S management is. The facilitation of OH&S is supported by management's allocation of finance to reap economic benefits through the return on investment and optimisation of investment. Investing in OH&S is the cost paid on the need for safety and that is necessary to reduce non-compliances (Hinze et al., 2013). Mwanaumo et al. (2018) and Zou and Sunindijo (2015) posit that reduced rates of accidents automatically reduces the cost incurred due to accidents. While OH&S is considered a moral and social responsibility, investing in OH&S addresses the right for every employee to safety at their workplaces, increases employee morale, reduces work stress related ailments, and helps contribute positively to the financial health and survivability of an organisation. The aspects to be considered in the study as constructs are resource provision for OH&S activities, financing occupational safety such as budgeting for personal protective equipment, the welfare of employees at projects, insurance of employees and compensation (See Table 1). According to Burt (2019), Buck (2014) and Paterson (2013), employers are required to invest in the health of employees by providing finance for medical services to increase alertness and sound mind so that productivity can be enhanced.

Table 1 Summary framework for the drivers for OH&S performance management from literature

Drivers	*Management Strategy*										*Employee Involvement*				*Finance*						*Training & Promotion*					*Actions for Continuous improvement*						*Hazard Ident. Mgt. & Review*				
Indicators / *Sources*	OH&S Policy	Management Committment / Involvement & Accountability	Integration of OH&S with Management	Safety work procedures/ Permit to work	Participation in OH&S Tool Box Tools	Emergency preparedness and response plan	Meeting contractual obligations	Ensuring Regulatory compliance	Management supervision	Legal /regulatory and contractual obligation	Planning, design and procurement	Involving employees in documented	Identifying hazards	Collaborative bargaining	Employee Participation	Financing occupational health	Financing Occupational safety (PPE)	Financing employee welfare facilities	Employee insurance	Employee compensation	OH&S Committee appoint	Financing regulatory requirements	Training in hazard identification	OH&S Training	Communication	Induction	Awareness	Preventive Approach & safety improvement	Incident reporting and investigation	Continuous monitoring of risks	Control measures	Ongoing documented inspections	Management review	Hazard identification/ Risk assessment	Project Supervision/ inspection	Waste management/House Keeping	Ergonomics management	Carrying out job task analysis
Mearns et al. (2003);	√	√			√					√	√						√				√		√		√	√										√
Hinze & Gambatese (2003)		√	√					√									√															√					
Basso et al (2004)	√	√						√									√	√					√				√							√			
Abudayyeh et al. (2004)		√										√																		√							
Teo et al. (2005)													√				√																				
Ng et al (2005)	√	√	√					√				√												√	√							√	√		√		√
Kheni (2008)										√															√		√	√	√								
Arkson and Hadisukumo (2008)		√			√												√			√				√													
Fernández-Muñiz et al. (2009)		√			√			√									√						√							√	√			√			
Rajendran & Gambatese (2009)													√						√						√							√					√

(continued)

Table 1 (continued)

Drivers	*Management Strategy*										*Employee Involvement*				*Finance*						*Training & Promotion*					*Actions for Continuous improvement*						*Hazard Ident. Mgt. & Review*				
Indicators	OH&S Policy	Management Commitment / Involvement & Accountability	Integration of OH&S with Management	Safety work procedures/ Permit to work	Participation in OH&S Tool Box Tools	Emergency preparedness and response plan	Meeting contractual obligations	Ensuring Regulatory compliance	Management supervision	Legal /regulatory and contractual obligation	Planning, design and procurement	Involving employees in documented	Identifying hazards	Collaborative bargaining	Employee Participation	Financine occupational health	Financing Occupational safety (PPE)	Financing employee welfare facilities	Employee insurance	Employee compensation	OH&S Committee appoint	Financing regulatory requirements	Training in hazard identification	OH&S Training	Communication	Induction	Awareness	Preventive Approach & safety improvement	Incident reporting and investigation	Continuous monitoring of risks	Control measures	Ongoing documented inspections	Management review	Hazard identification/ Risk assessment	Project Supervision/ inspection	Waste management/House Keeping	Ergonomics management	Carrying out job task analysis
Sources																																						
Reiman et al. (2012)		√							√																												
Reiman & Pietikainen (2012)					√		√					√				√			√			√	√					√		√		√	√		√			
Priyadarshani et al (2013)		√		√	√												√													√			√					
Wachter & Yorio (2014)					√			√			√	√			√		√					√	√				√			√	√		√		√			
Podgorski (2015)													√																									
Tappura (2017)		√															√	√																				
Mohammadfam et al. (2017)	√				√			√					√			√					√	√						√				√			√			√
Liao & Chang (2017)	√																													√			√			√		√
Agumba & Haupt (2018)		√			√		√			√				√			√	√				√	√			√	√		√	√							
Mustapha et al. (2018)		√	√									√						√					√					√				√						
Mwanaumo and Mambwe (2019)	√	√	√					√							√		√		√							√		√				√			√			

2.3 Employee Involvement

Employee involvement is an essential driver in OH&S performance management and is laid down in the Health and Safety Executive Strategy for the UK for 2009, the Australian SafeWork plans 2010, the Occupational Health and Safety Act 2010 of the laws of Zambia, including many others. According to Raines (2011), employee involvement relates to employees' engagement in a way that furthers the organisation's interests on OH&S related issues. Thus, employee involvement is directly correlated with employees' level of participation in their work processes and activities. However, authors such as Manu (2020), Wachter and Yorio (2014), Herrera (2012) and Fernández-Muñiz et al. (2009) argued that failure to involve employees has a negative perception on management, considering not to be serious about OH&S, hence, increase in the rate at which safety rules, are broken. This affects OH&S performance despite compliance, management commitment, and training. According to Mwanaumo and Mambwe (2019), Manu et al. (2019) and Raines (2011), strengthening employee involvement and engagement saves organisations large sums related to OH&S costs. Some of the measures found from literature under the finance driver are consulting employees in OH&S planning, employees allowed to make OH&S suggestions, and employees attend OH&S meetings, and are important to improving OH&S (as indicated in Table 1).

2.4 Training and Promotion

Training and promotion in OH&S are essential for workers to attain the OH&S knowledge and strong awareness of safe and correct practices so that OH&S risks are minimised in a dynamic environment which is ever changing such as at projects. Manu (2020) added that OH&S training is part of human resource development and is a human resource strategy that aims to develop employees' full potential irrespective of the possibility of use at current jobs. The World Health Organisations (2020) postulate training in OH&S as the set of activities that provide employees with the knowledge and skills to enable them do work safely and effectively. Promotion is the means with which procedures and processes are applied in an organisation to develop, improve and sustain OH&S through awareness-raising and behaviour change (Arkson & Hadisukumo, 2008; Fernández-Muñiz et al., 2009; Herrera, 2012; Manu, 2020). According to Zou and Sunindijo (2015), employees feel part of the organisation when they gain new knowledge, making them feel accountable to OH&S issues. Communicating information through various means can be done carefully through easy means that allow quick understanding of the message for unskilled employees to be able to understand (Ahmed et al., 2021). However, Agumba (2013) argues that employees need to be competent enough to do their job in order to reduce mistakes that would lead to accidents and injuries. Inducting new employees,

visitors, and other contractors on-site reduces the risk of project incidents. Some of the adopted variables are indicated in Table 1.

2.5 Hazard Identification Management and Review

Employees are subjected to various work-related health risks that affect the overall objectives of OH&S management. When conducting a risk assessment and hazard identification exercise, it is important to take note of the type of hazards and their root cause. By managing risks, identifying risks, assessing, controlling, monitoring, and reviewing, it entails that incidents are minimised. However, the biggest motivation depends on the financial beneficiation of loss reduction that leads to improved profitability for an organisation and the reduced number of injuries (Mengoli & Debarberis, 2008). Therefore, indicators to this driver include hazard identification, risk assessments, controlling risks, documented inspections, completion of supervisor safety inspections, incident investigation, analysis of job tasks at projects, housekeeping, and management of waste on sites (See Table 1). However, the variables, reviewing available risk information and risk communication were found to be significant based on the literature reviewed (Floyde et al., 2013; Wang et al., 2016).

2.6 Actions for Continuous Improvement

The study considered variables such as incident reports, workplace safety improvement, preventive and proactive measures, corrective measures, control measures, management reviews, continuous monitoring and mitigating of hazards and risks, and internal audits after literature review as indicated in Table 1. However, Cheng et al. (2012) argued that actions for continuous improvement of OH&S during project implementation, which is the longest phase of the contract, and the contractor of SSC on site are left in most cases, on their own. During this period, there is a need for audits, hazard inspections and risk assessments continuously to make sure that performance in OH&S management is enhanced and in place. It is expected that the appointed SSC has the right profile in implementing the project while being careful with the OH&S requirements such as placing positive/proactive preventative measures with the view to minimise accidents, injuries, and damage to property (Schein, 2011).

2.7 Employee Wellbeing

Employee wellbeing is becoming an increasingly significant and pertinent factor for consideration in modern workplaces to improve OH&S performance. According to the Health and Executive (HSE, 2018), Newman et al. (2020) issues employee

wellbeing is within the duty of care for employers and once implemented, it ensures performance, quality and productivity thus leading to the effectiveness of firms. Further, Reinert (2016), Spence (2015) and Koban et al. (2013) that workplace strass relates to the adverse response of employees to excessive pressures and various demands subjected to them at work. This causes employees to fail to cope with work demands, the environment leads to reduced productivity and reduced physical and mental health. Nonetheless, this outcome increases the costs of reduced productivity, absenteeism, stress-related ailments, employee turnover and civil claims related to accidents (Burt, 2019; HSE, 2018; Koban et al., 2013; Liao & Hsaio, 2013; Manu, 2020). It was argued by Leka and Jain (2013) that management is mandated to identify and address signs of employees that are stresses out at an early stage so that timely interventions to prevent escalation of problem can be done. Management should ensure that activities at the workplace are improved through balanced work, resource leveling and proper interpersonal communication.

2.8 Provision of Occupational Health and Safety Services

The ILO's C161 Convention on Occupational Health and Safety services (International Labour Organisation, 1985) posit the need to provide preventive functions and advise employers and employees on establishing and maintaining safe and healthy working environments for physical and mental health. The convention also stated that the adaption of work capabilities from government or autonomous bodies to facilitate OH&S so that it performance is enhanced. Hence, According to Chinda and Mohamed (2008) the provision of OH&S services interrelates with the laid down policies attained in SSCs concerning OH&S issues for a better work environment. These services include supporting the SSCs in technical aspects such as drawing up OH&S Plans at a very subsidized rate, including other technical aspects like OH&S management, ergonomics, work-injury investigations, and information for new interventions the work environment. Rajendran and Gambatese (2009) noted that because SSCs are constrained with resources to comply with all legal requirements for OH&S, it is justifiable that partnerships are created with government through OH&S service unit to provide consultancy services required for the daily operation of SSCs at projects.

3 Materials and Methods

The study assessed the drivers for the improvement of OH&S performance management by SSCs in Zambia by using a Delphi technique, which is a purely qualitative study, through the use of a structured questionnaire as a data collection tool. The adoption of the questionnaire was driven by its simplicity and capability to cover a wide range of audience within a shorter period of time with no interaction (Aigbavboa,

2013). The Delphi approach is a predictive, consultative structural qualitative technique that is intuitive and subjective in nature (Aigbavboa, 2013; Alomari et al., 2018). The process utilised questioning that is continuous from a panel of experts in a way in which feedback is made (Ameyaw & Chan, 2015). Additionally, the approach was adopted because of limited previous research that assess the drivers for improving OH&S in the electricity industry in Zambia for SSCs.

The survey was conducted among Zambian experts practicing in the electricity industry and policy makers composed of qualification types ranging from construction engineers, electrical engineers, environmental experts, public health experts, health and safety experts and medical and wellness expert. Thus, a total of 11 experts were approached to take part in the survey. This number is sufficient according to Alomari et al. (2018) and Skulmoski et al. (2007), Nazir et al. (2020). A purposive and random sampling technique was used in which the selection criteria was purposely thought through. The selection of panel of experts was based on fulfilling at least 50% of the set selection criteria (Slade et al., 2014). The selection criteria included: professional body membership; being involved in OH&S activities at organisational to national level; at least five (5) years experience working in OH&S in the Zambian electricity industry; academic background as a Faculty member; and higher Education Background. Hardison et al. (2014) criteria were based on work experience in the field of study with a minimum of five years, level of involvement in jobs related to the study topic, and knowledge around the study area. A similar criterion was developed by Alomari et al. (2018) and Wikes (2015).

The eight drivers from literature were used as themes for the questionnaire with a total of 88 structured questions that were open-ended in nature. Two iterations of the Delphi process with the panel of experts were carried out and they who rated the structured Delphi questionnaire using a 10-point Likert scale of influence that was based on the statistical scale of agreement. The influence scale was 1–2 = strongly disagree, 3–4 = disagree, 5–6 = neutral, 7–8 = agree and 9–10 = strongly agree, to attain the study objectives. The analysis was used to investigate consensus by using Statistical Package for Social Sciences (SPSS) software. Experts were requested to rate the degree of influence of the drivers and indicators on OH&S performance management by SSCs at projects. Experts were given an opportunity to make comments in the second iteration of the Delphi process. The experts were asked to fully explain the response changes when situations where scores more than one unit or less than one unit of the group median were rated. Hence, the second-round questionnaire indicated the group medians of the categorised indicators under key elements. Analysis was done using group median, mean, and interquartile deviation (IQD) between 0 and 1 (Ameyaw & Chan, 2015; Hu et al., 2016). Experts were updated with the feedback from each iteration's results and could re-rate the indicators.

To attain consensus, 60% was used as a cut-off for the acceptability of a statement. This means that common consent was achieved on each question with at least 60% agreement by experts. Other studies proposed 100% cut-off, while others proposed at least two-thirds of the agreement to be considered consent (Aigbavboa, 2013; Ameyaw & Chan, 2015). The consensus scale used for the study, as informed by Skulmoski et al. (2007) ranged from strong consensus: median ($\leq$9–10.00); mean

(≤8.00–10.00); and IQD (≤1.00), ≥80% ≤ 100% (8.00–10.00) to poor consensus: median (≤6.99); mean (≤5.99); and IQD (≥2.10 ≤ 3.00), ≤59% (5.99).

The study recognised the possibility of selection bias among the respondents since the experts work within the study's areas. This is normally abridged using the random sampling approach (Smith & Noble, 2014) but it was not possible for this study as the total population involved in OH&S performance management in the electricity was difficult to determine. While this is a major limitation to the study, the result validity was ensured through the use of specific questions and well-defined terms to ensure clarity (Yousuf, 2007). The Cronbach reliability test for the reliability of the questionnaire was in each field was also tested. The Cronbach alpha value should be between 0 and 1, indicating reliability of the questionnaire when high values attained (Moser & Kalton, 1999).

4 Results and Discussion

4.1 Background Data

Experts engaged in taking part in the study were all from Zambia with a background and experience in OH&S management and drawn from the electricity industry. From the 11 experts, only five (5) have had an academic experience. In terms of years of experience, all experts had worked more than 5 years in the industry, with the lowest working for 6 years and the highest with 27 years of experience. The minimum level of education for the experts was a Bachelor with the highest being a Doctorate level. Hence, the experts were equipped academically. All the experts had professional membership and were involved in OH&S activities from organizational to national level. However, only 54% had an academic background experience while 46% did not have. All the 11 experts who accepted taking part in the Delphi survey responded giving a 100% response rate otherwise, any reduction to less than 85% would have compromised the validity of the results.

4.2 Drivers to Efficient Occupational Health and Safety Performance Management

Management Strategy

The results in Table 2 shows the different drivers for management strategies indicated that from the second round, there were 13 variables assessed sub-elements, and all met consensus as perceived by the experts. The median indicated a very high influence (VHI: 9–10). With a cut-off score (IQD ≤ 1), there was a strong consensus of the remaining 13 indicators since the scores were between 0.00 and 1.00, indicating

Table 2 Management strategy driver

Management strategy	Median	Mean	IQD ≤ 1	Cronbach alpha
Having an OH&S policy in the firm	9	8.27	1.00	0.96
Management is committed to safety issues	9	8.55	0.50	
Management is accountable for OH&S	8	7.73	0.00	
Integration of OH&S issues with management functions	8	7.36	0.00	
Formulating safe work procedures	9	8.36	0.50	
Issuance of permit to work is done	8	7.64	1.00	
Availability of emergency preparedness plans	9	8.36	0.50	
Compliance to regulations/contracts)	7	7.40	0.00	
Planning and designing of OH&S	9	7.64	1.00	
Procuring systems of OH&S in place	8	7.45	0.50	
Ensuring participation of stakeholders	8	7.73	1.00	
Management communicating all OH&S issues	8	7.64	0.00	
Conducting safety meetings	9	8.09	1.00	

Note SD Standard deviation; *IQD* Interquartile deviation

80–100% consensus. The SD values indicated consistency in the overall results, including the Cronbach alpha result of 0.96, indicating correlation and reliability.

Finance

Only six variables reached a consensus in the second round. The experts did not propose including any elements that would affect the performance management of OH&S. The median indicated a very high influence (VHI: 9–10), which is very significant to the study. Only one indicator had the median indicating a strong influence of (HI: 7–8) and hence significant (7–8.99); and a mean of (8–10) was attained. The IQD was within the cut-off score (IQD ≤ 1), hence there was a strong consensus since the scores were between 0.00 and 1.00, indicating 80–100% consensus (Table 3). The SD values indicated consistency in the overall results, including the Cronbach alpha result of 0.93, indicating correlation and reliability.

Employee Involvement

In the second round, employee involvement had four drivers that reached a consensus. The experts did not propose new variables for OH&S performance management even though the opportunity was given. The median indicated a very high influence (VHI: 9–10), very significant (1–10). Only one driver had the median indicating high influence (HI: 7–8) and hence significant and mean of (6–7.99), because the IQD was within the cut-off score (IQD ≤ 1), hence there was a good consensus since the scores were between 0.00 and 1.00 indicating 80–100% and 60–79%. The consensus was met as the sub-elements were above 60% set criteria (Table 4). The SD values

Table 3 Finance driver

Finance	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Resources for OH&S activities	10	8.00	0.64	0.50	0.93
Providing the required PPE for employees	10	8.27	0.64	0.50	
Making available finance for correct tools and equipment	9	8.28	0.64	1.00	
Making available a budget for welfare of employees	8	7.82	0.64	1.00	
Ensuring employees are covered with insurance	9	8.00	0.78	1.00	
Ensuring a budget for compensation when required	9	8.10	0.83	0.50	

Note SD Standard deviation; *IQD* Interquartile deviation

Table 4 Employee involvement driver

Employee involvement	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Immersing employees in OH&S activities	10	9.45	0.78	1.00	0.97
Engaging employees in inspections	8	7.45	2.27	1.00	
Taking part in the identification of hazards and assessing risks	7	7.45	0.99	1.00	
Employees to be involved in accident investigations	10	9.55	0.89	0.50	

Note SD Standard deviation; *IQD* Interquartile deviation

indicated consistency in the overall results, including the Cronbach alpha result of 0.97, indicating correlation and reliability of the results.

Training and Promotion

According to the results, eight drivers achieved consensus for the training and promotion dimension. The median indicated a very high influence (VHI: 9–10) from three (3) variables, hence very significant (1–10). The remaining five (5) sub-elements had the median indicating strong influence (HI: 7–8) and hence significant (7–8.99) and mean of (8–10). All the sub-elements had the IQD ranging within the cut-off score (IQD ≤ 1), hence there was a strong consensus since the scores were between 0.00 and 1.00, indicating 80–100% consensus (see Table 5). The SD values indicated consistency in the overall results, including the Cronbach alpha result of 0.94, indicating correlation and reliability of the results.

Hazard Identification, Management and Review

Hazard identification, management and review indicated that nine (9) sub-elements reached consensus. The median indicated a very high influence (VHI: 9–10) from five (5) variables, hence very significant. The remaining four (4) sub-elements had

Table 5 Training and promotion driver

Training and promotion	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Training in OH&S aspects	9	8.45	0.88	0.50	
Ensuring orientation and induction in OH&S	9	6.18	0.72	1.00	0.94
Carrying out site specific inductions	10	6.55	0.86	1.00	
Clearly disseminated verbal communication	8	7.64	0.48	1.00	
Written instructions are properly communicated	8	7.55	0.57	0.50	
Training in PPEs for employees is done	8	7.36	0.78	1.00	
Signage/posters on OH&S requirements at projects	8	7.73	0.86	1.00	
OH&S awareness programs are done at projects	8	7.91	0.67	0.50	

Note SD Standard deviation; *IQD* Interquartile deviation

the median indicating high influence (HI: 7–8). The mean generally ranged from 7.73 to 9.27. The SD values indicated consistency in the overall results including the Cronbach alpha result of 0.98 indicating correlation and reliability of the results. All the drivers had the IQD ranging within the cut-off score (IQD ≤ 1), hence, a strong consensus indicating 80–100% consensus (Table 6). The SD values indicated consistency in the overall results including the Cronbach alpha result of 0.98 indicating correlation and reliability of the results.

Table 6 Hazard identification, management and review driver

Hazard identification, management and review	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Conducting hazard identification	9	7.91	1.74	1.00	0.98
Conducting risk assessments	8	7.55	0.85	0.50	
Controlling hazards at projects	8	6.73	0.86	1.00	
Conducting documented inspections	9	7.91	0.72	1.00	
Completion of supervisor safety inspections	8	7.73	0.66	1.00	
Carrying out incident investigations	8	7.27	0.75	0.50	
Analysis of job tasks at projects	9	7.55	1.75	0.50	
Housekeeping at project sites	9	8.18	1.99	1.00	
Management of waste at projects	9	8.09	1.86	1.00	

Note SD Standard deviation; *IQD* Interquartile deviation

Table 7 Actions for continuous improvement driver

OH&S culture for continuous improvement	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Making sure all incidents are reported	9	8.00	0.91	1.00	0.98
Ensuring that workplace safety improvements are done	8	7.73	1.67	1.00	
Conducting prevention and positive actions	9	7.73	1.57	0.50	
Ensuring that corrective actions are undertaken	9	7.82	0.67	0.50	
Controlling measures are put in place	8	7.36	0.50	1.00	
Making sure management review OH&S strategies	9	8.10	0.45	0.50	
Continuously monitoring and mitigating risks	8	7.55	0.89	1.00	
Ensuring that self/internal auditing exercises at projects	9	7.56	1.02	1.00	

Note SD Standard deviation; *IQD* Interquartile deviation

Actions for Continuous Improvement

The second-round results showed results with eight variables reaching consensus. The median indicated a very high influence (VHI: 9–10) with five variables, hence very significant. The remaining three (3) drivers had the median indicating high influence (HI: 7–8) and hence significant (7–8.99) and mean of (8–10). All the drivers had the IQD ranging within the cut-off score (IQD ≤ 1), hence there was a strong consensus indicating 80–100% consensus (Table 7). The SD and Cronbach alpha was within the acceptable range.

Employee Wellbeing

As indicated in Table 8, the results show that 11 variables were accepted. The median indicated a very strong influence (VHI: 9–10) from eight variables, hence very significant. The remaining three (3) sub-elements had the median indicating strong influence (HI: 7–8) and hence significant (7–8.99) and mean of (8–10). All the sub-elements had the IQD ranging within the cut-off score (IQD ≤ 1), hence there was a strong consensus since the scores were between 0.00 and 1.00, indicating 80–100% consensus. The SD values indicated consistency in the overall results, including the Cronbach alpha result of 0.99, indicating correlation and reliability of the results.

Table 8 Employee wellbeing driver

Employee wellbeing	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Ensuring pre-counselling to employees	10	9.64	0.64	0.50	0.99
Work design that encourages a balanced work-life	9	9.27	0.62	1.00	
Managing of stressed-out employees	9	9.09	0.64	0.50	
Overtime and number of working hours to be managed	9	9.36	0.64	1.00	
Integrity and fairness for job satisfaction	8	8.64	0.64	1.00	
Social support system that promotes open conversations	9	9.27	0.45	0.50	
Provision of welfare facilities at projects	9	9.00	0.60	0.00	
Levelling and job matching at projects	9	8.91	0.67	0.50	
Aligning wellness programs to firm's strategy	8	8.64	0.77	1.00	
Integrating wellness as part of OH&S management policy	8	7.82	0.72	1.00	
Ergonomic/physical arrangement of work	9	9.09	0.79	0.50	

Note SD Standard deviation; *IQD* Interquartile deviation

Provision of Occupational Health and Safety Services by Government

The provision of OH&S services results indicated in Table 9 that 10 drivers were accepted. The median showed a very high influence (VHI: 9–10) from six (6) variables, hence very significant. The remaining four (4) sub-elements had the median indicating strong influence (HI: 7–8) and hence significant (7–8.99). Generally, the mean ranged from (8–10). All the sub-elements had the IQD ranging within the cut-off score (IQD ≤ 1), hence there was a strong consensus since the scores were between 0.00 and 1.00, indicating 80–100% consensus. The SD values indicated consistency in the overall results, including the Cronbach alpha result of 0.95 indicating correlation and reliability.

The study objective of identifying OH&S experts and determining drivers and indicators that can be used in the implementation of OH&S performance management at projects by SSCs in the Zambian electricity industry was met. This is one of the few studies reported to have established a set of drivers for the electricity industry in Zambia to improve OH&S performance management. These drivers include management strategy, finance, employee involvement, training and promotion, actions for continuous improvement, hazard identification management and review, employee wellbeing and provision of OH&S service.

Table 9 Provision of occupational health and safety services driver

Provision of OH&S services	Median	Mean	SD	IQD ≤ 1	Cronbach alpha
Advisory role in OH&S hygiene and ergonomics	8	8.36	0.77	1.00	0.95
Providing rehabilitation services	9	8.73	0.75	1.00	
Information on OH&S for SSCs	8	8.18	0.72	1.00	
Orientation services for SSCs	9	8.73	0.75	0.50	
Surveillance of health, safety and environmental risks	9	8.82	0.83	0.50	
Developing OH&S policies, guidelines, work procedures	9	8.27	0.86	0.50	
Conducting investigations, inspections and reporting	9	9.09	0.67	0.50	
Conducting audits at project	8	8.45	0.99	1.00	
Periodic health examinations at project sites	8	8.30	0.76	1.00	
Services of preventive and control measures	9	9.27	0.62	1.00	

Note SD Standard deviation; *IQD* Interquartile deviation

As one of the key elements, management strategy indicated strong consensus in all the rounds. The results for PPIs such as OH&S policy, management accountability, emergency preparedness and response plans, planning safe work procedures were consistent with the literature (Agumba, 2013; Fernández-Muñiz et al., 2009; Mwanaumo & Mambwe, 2019). Financing is a relevant aspect in improving OH&S performance which is left out in some existing studies. Availability of financial resources for OH&S activities is cardinal in improving OH&S as it allows the SSC prevention of incidents through building capacities and providing compensation and welfare for employees. The studies are consistent with Alomari et al. (2018), who mentioned that finance also allows for training, equipment, and welfare facilities. Training of employees and promotion of OH&S through indicators such as communication, awareness, signage came to a consensus with the indicators and the indicators were consistent with Hu et al. (2016) and Hardison et al. (2014).

Employee involvement is significant in cultivating a safety culture for SSCs in the electricity and all the PPIs were maintained in both rounds (Mwanaumo & Mambwe, 2019). Once employees are involved, the fee a sense of belonging and are motivated to improve at the same time this allows them to be able to identify hazards and manage the risks since they are trained to do so and prevent incidents such as accidents. Further, the wellbeing of employees, as asserted by Bergh et al. (2014), and provision of OH&S services, as emphasized by Mustapha et al. (2018) are limited in most existing frameworks as key elements, yet they are important aspects in meeting the sustainable development goal number three and the African Agenda 63(3) on

health and the ILO (2001) provisions on OH&S performance management. Therefore, contracting firms such as SSCs who are unable to conduct OH&S activities should be able to access services from the government departments in-charge of health and safety at a subsidized or no charge in order to reduce accidents, injuries and fatalities at the same time increasing information flow and networking on all aspects of OH&S.

Discussion and Implication of the Overall Drivers for OH&S Performance Management

From the attained findings of the group mean of each dimension, it can be deduced that while all the eight drivers appraised in this study are significant as their group mean averaged above 6.0, the major dimensions that require significant attention are finance, management strategy, employee involvement, actions for continuous improvement, employee involvement, training and promotion, hazard identification management review, and with mean group values of 8.08, 7.86, 7.74, 7.66, 7.65 and 7.51 respectively as shown in Fig. 1. Though very cardinal in ensuring efficient OH&S performance management, employee well-being (7.37) and provision of OH&S services (7.10) should also be considered moderate drivers to OH&S performance management for SSCs in the electricity industry Zambia.

Hence, the diagramatic version of the significant drivers in relation to the other drivers based on the expert perspective is portrayed in Fig. 2. The minimum mean of 6.6 was attained for the variables selected under each driver, bearing in mind that this mean value and above were acceptable. Also, all the indicators selected were dependent on the attainment of the IQD being less than or equal to one and more than zero or equal to zero. The findings indicate the opinion of the experts, that having financial base placed aside for the implementation of OH&S at projects and making

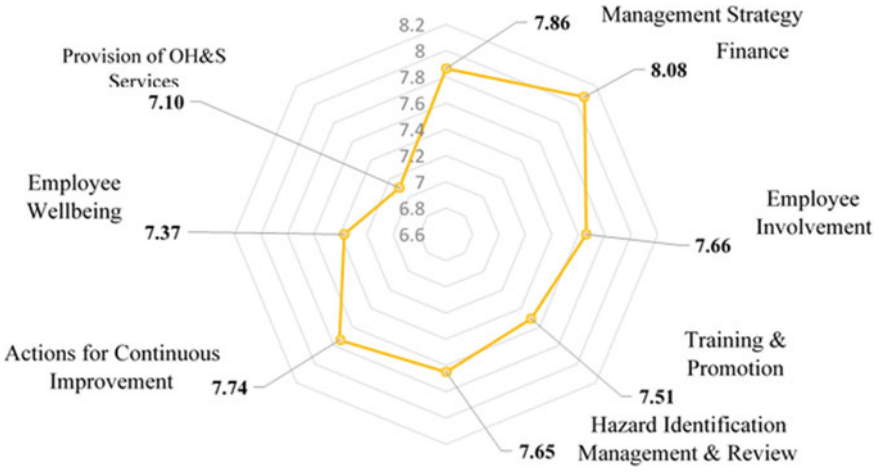

Fig. 1 Overall group mean of the OH&S performance management drivers

it vital for the improvement of OH&S performance management by SSCs in the electricity industry.

This is justifiable as most OH&S activities can only take into effect if management is committed to allocating a budget to finance training, procurement of PPE, tools and equipment, compensation, and insurance of employees. Additionally, planning to finance OH&S at projects is not as expensive as the cost of an accident, fatality and injury as there are more indirect than direct costs (Mambwe & Mwanaumo, 2017; Wang et al., 2016; Zou & Sunindijo, 2015). This allows for efficiency in the organisation, market profitability and market share, productivity, and emergency preparedness in unforeseen risks (Windapo & Oladapo, 2012).

In the same vein, the role of management strategy cannot be overemphasized as it allows for the development of policy on OH&S in line with the company objectives so that OH&S performance management is improved through efficient indicators. It shows how much management is commitment to improving safety (Alomari et al., 2018; Gunduz & Laitinen, 2017; Mwanaumo et al., 2018). Additionally, once finance driver and Management strategy are in place, the rest of the drivers fall into place. That is, training and promotion, involvement of employees and implementing actions for continuous improvement can be undertaken. Also, with the policy in mind, hazards are identified managed and reviewed, while the wellbeing of employees is considered and there is a continuous collaboration on OH&S with OH&S service providers such as government units and private entities as is observed from. From the results, a diagrammatical illustration of the key drivers for OH&S performance management was developed.

5 Conclusions

The study assessed the drivers that lead to efficient OH&S performance management for SSCs in the electricity industry in Zambia. Based on the finding, it can be concluded that there are eight drivers with 69 indicators from the initial 88, for OH&S performance management required for its improvement and are considered significant in Zambia. The implication of adopting such drivers is reduced OH&S accidents, incidents, and fatalities, increase productivity and firm's market share at the same time improve OH&S performance management at projects. Equally significant to this study is the attainment of OH&S culture in the firms and as an industry as a whole. The introduction of employee wellbeing driver and provision of OH&S services will positively affect the health of employees and encourage policy development, inspections, audit and emergency preparedness.

The study results contribute to the existing knowledge body and bring about to the driver significance in improving OH&S performance management efficiently. The study recommends that small-scale contractors adopt the findings in the electricity industry to reduce injuries, accidents, fatalities and diseases at projects. The developed concept and its drivers are workable, adaptable and efficient and will be helpful for SSCs and stakeholders in the attainment of zero harm through the improvement

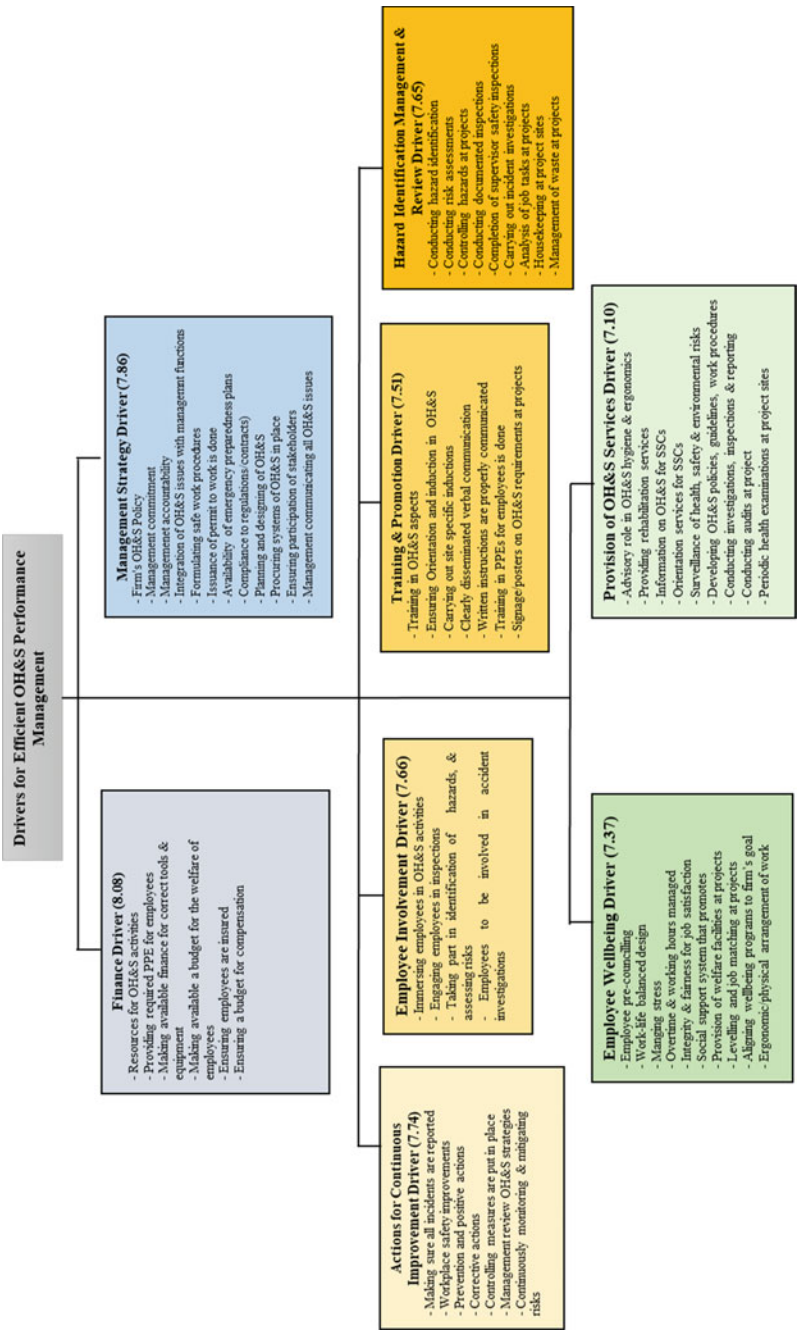

Fig. 2 Developed key drivers for small-scale contractors' efficient occupational health and safety performance

of OH&S performance management. However, it should be noted that there were some limitations such as biasness in the sample for the study and the need for a larger population of experts in the industry.

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Rule Based Safety Checking in Scaffolds by Integrating Building Information Modeling (BIM) and Safety Management

Aneetha Vilventhan and Subhadarshi Mohapatra

Abstract The construction industry is one of the most accident-prone sectors in the world. The lack of strict adherence to guidelines and safety standards is one of the major contributing factors to safety hazards. Identifying safety risks before the start of construction is very crucial. This requires incorporating safety parameters into the design stages of the project. A rule-based safety checking model by integrating safety management with Building Information Modelling (BIM) will facilitate safety checking in the design stages. This chapter discusses how the safety regulations are converted to rulesets and integrated to BIM to identify safety risks involved in the scaffolding structures during the design stage of the project. The rule-based safety checking approach will evaluate the BIM model if regulations and specifications are followed as mentioned in the safety codes. The integration of safety management with BIM will enable communicating safety issues with the stakeholders and reduce accidents relating to improper scaffoldings.

Keywords Safety management · Building information modelling · Rule-based checking · Model checking software

1 Introduction

The construction site is infamous for a multitude of safety and health-related risks. Often physical injury, loss of life, property damage, economic loss, or probable damage to the environment are encountered during construction activities. In the United States, around 15% of fatal injuries occur in the construction site and over 9% of total workdays were lost due to the occurrence of fatal injuries (Yoon et al., 2013). Injuries in a construction site are caused by many reasons such as falling from a height or getting struck by falling objects due to the absence of guard rails, electrocution due to contact with exposed power lines, lack of knowledge, and improper use of Personal Protective Equipment (PPE) getting crushed or caught in between objects,

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trench collapses, overexertion, fires, and explosions. Of the various causes, it is identified that the major injuries occurred due to accidents related to poor scaffolding in a construction site. These accidents can be prevented by following proper safety guidelines at the construction site (Khan et al., 2019). Hence a safety planning is necessary to mitigate safety risks involved in construction sites (Han et al., 2019).

The existing system of safety management mostly relies on visual inspection on-site and validating whether all work complies with the rules and regulations prescribed in the safety handbooks or standard codes of practice. Since various techniques and practices are followed in a construction process, monitoring of construction sites is complex and it is difficult to keep a constant observation for detection of safety risks. This requires predetermination of safety risks involved before the start of the construction project. The current safety planning approaches are primarily text-based, standalone, or check-sheet type tools, which are accessed either via paper or through software interfaces (Zhang et al., 2013). Despite the advancements in other areas of construction projects, safety management still follows a primitive approach which is cumbersome and ineffective. It is often emphasized to adopt newer technologies such as BIM for safety management in construction (Hu & Zhang, 2011). Hence, it is essential to develop a rule-based safety checking approach by integrating BIM and safety management to mitigate various accidents caused by improper scaffolding in construction sites. This allows identifying safety risks during the design stage of the project and enables making design alterations and preventive measures before the start of the construction.

This Chapter is structured as follows: the next section discusses on the use of BIM and safety management in construction. Later, the chapter discusses on the framework for integrating BIM, safety management, the next section discusses the study conducted in India that developed an automatic rule-based safety checking integrating BIM, and safety management, and the results are discussed in detail through implementation in a real case of a residential building project. Lastly, discussion and conclusion are provided.

2 Use of Integrating BIM and Safety Management in Construction

Building Information Modelling (BIM) is a process that uses various tools and technologies to develop digital models and simulate construction projects throughout their lifecycle. BIM enhances communication between all parties involved in every single phase of the project and improves collaboration and coordination (Azhar et al., 2012). BIM is being used for production planning and day-to-day production control (Sacks et al., 2010).

Though BIM has various applications during the design and construction stages of the project, the integration of safety with BIM during the design stage of the project is still in the development stage (Ganah & John, 2015). To prevent injuries

and save the lives of construction workers, there should be considerable interest in improving worksite safety through safer design and work method statements using BIM (Chi et al., 2012). The current applications of BIM in safety management were used for developing automated rule-based safety checking system for detecting fall-related safety hazards (Zhang et al., 2013), automated real-time safety monitoring of construction sites using Bluetooth devices (Park et al., 2017), identifying clashes in temporary scaffolding systems (Teo et al., 2016), integrating safety management during facility management of buildings (Wetzel & Thabet, 2015), integrating augmented reality in the design of fire safety system (Chen et al., 2020), designing automated safety rules-based identification of unsafe design factors in Construction (Hongling et al., 2016), designing of temporary structures like scaffolds (Wang et al., 2015). However, they were limited to accidents that occur due to falling from height and getting struck by falling objects.

There are studies on integrating BIM with safety management like automated rule-based safety checking and monitoring for mitigating fall-related hazards ((Park et al., 2017; Zhang et al., 2013) and for the design of temporary scaffolding structures (Wang et al., 2015). However, the use of BIM integrated with safety management in developing an automated rule-based safety checking system for the design of scaffolding systems is not explored. This chapter discusses the study conducted in India that integrates BIM and safety management for rule-based safety checking of scaffolding structures during the design stage of a construction project and demonstrates the implementation in a real case of a residential building project. This helps in detecting safety risks before the project execution and also eliminates any possible risks as the project progresses.

3 Framework for Implementing Rule-Based Safety Checking System in BIM

A framework for developing and implementing an automatic rule-based safety checking is shown in Fig. 1.

Parametric 3D models of the building and scaffoldings are developed using modeling software such as Autodesk Revit. The developed models were then imported into model checking software Solibri and rule-based safety checking has been performed. The safety rules were obtained from the handbook of CPWD (Central Public Works Department), Codes of Bureau of Indian Standards, and OSHA's Handbook and were codified in machine-readable format to establish safety rulesets. Through the model checking software (Solibri), the developed 3D BIM model was analyzed to identify associated safety risks. Potential errors and corrective measures were reviewed and mitigation measures were implemented in the 3D BIM model, thereby allowing to mitigate safety risks during the design stage of the project. The implementation of the proposed automatic rule-based safety checking

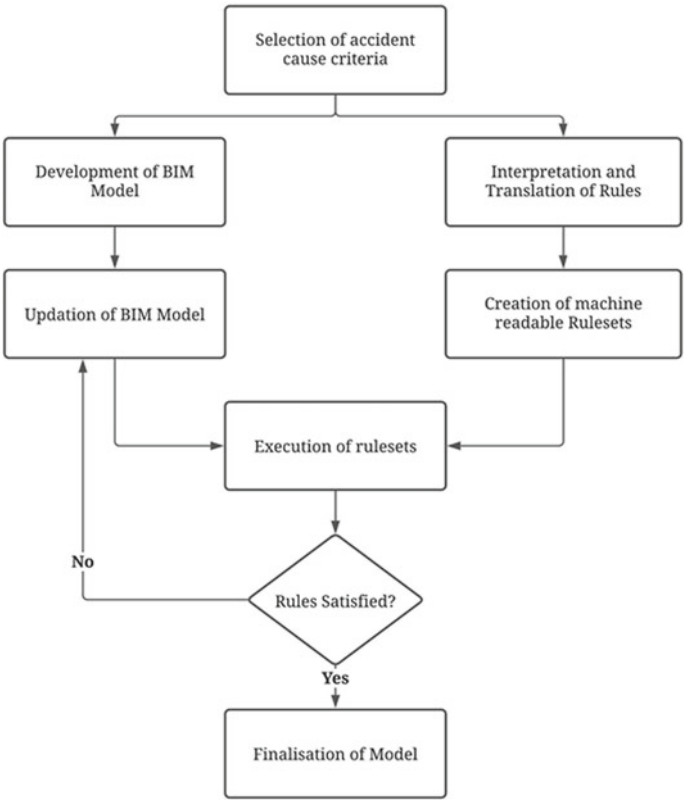

Fig. 1 Framework for implementing rule-based safety checking system in BIM

and the results are discussed in detail through implementation in a real case of a residential building project.

4 Case Study: Implementation of Proposed Automatic Rule-Based Safety Checking

4.1 Development of BIM Model

A 3D BIM model was developed using proprietary software such as Autodesk Revit. Custom 3D parametric models of scaffolds were created and saved as Revit scaffolding family files in.rfa format. Scaffolds such as simple double pole scaffold, diagonal braced double pole scaffold, and multiplatform double pole scaffold were developed as Revit families as shown in Fig. 2. Individual elements such as frames,

platforms, toe boards, and guardrails were used in developing a scaffolding object. This allows identifying safety compliance with individual members in scaffolding while performing rule-based safety checks. The use of parametric modeling allowed changing the model parameters based on the project requirements and eliminated redundancy of 3D models. Further, the created scaffolding models were directly imported into the 3D BIM project model (in the format.rvt) and used in relation to the developed 3D building as shown in Fig. 3. The developed model was stored in an IFC format to facilitate interoperability between different software packages.

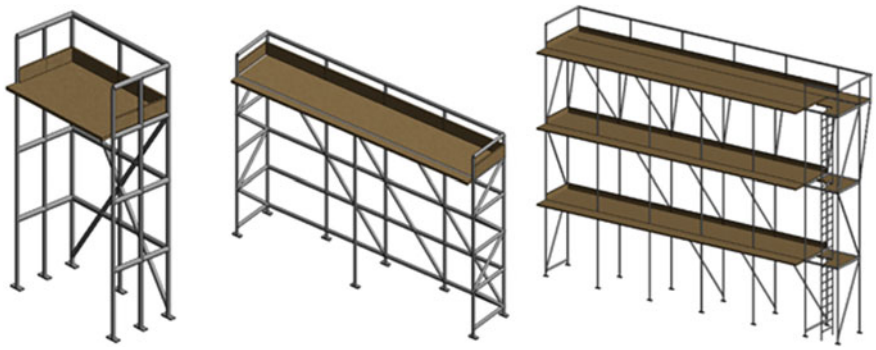

Fig. 2 Scaffold family created using autodesk revit

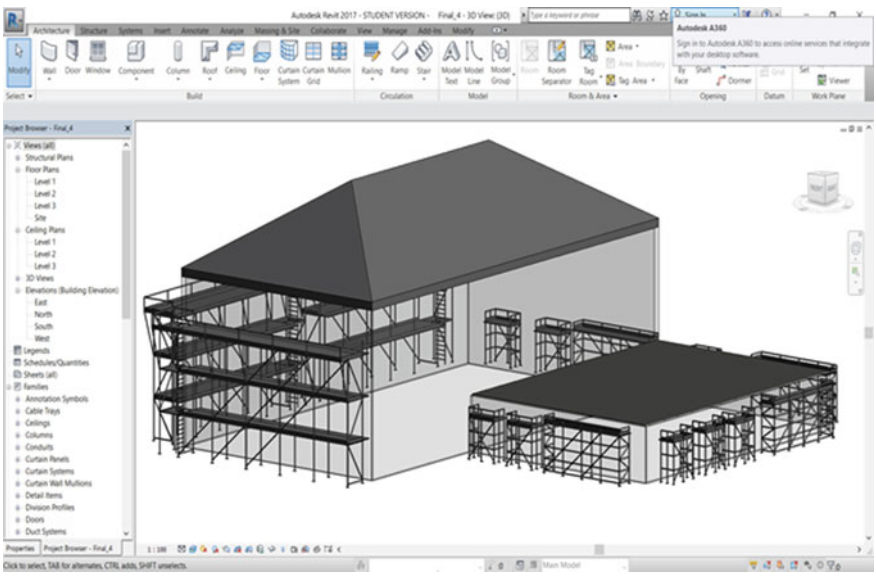

Fig. 3 3D Model of building with scaffolding families

4.2 Interpretation and Translation of Rules

To develop translation rules, the safety regulations prescribed in Central Public Works Department (CPWD) Safety Health and Environment Handbook, Indian Standard code of practice (IS 3696:1991 Part 1 and Part 1), and OSHA's Handbook (OSHA 1926 Subpart L dealing with safety regulations for Scaffolds and ladders and regulations) were considered. The rules prescribed in the safety standards were then coded and safety rulesets were created. The coding process allows machines to automatically read the specifications and regulations and perform compliance checks with individual elements in the 3D BIM model. In this chapter, safety in scaffolding is considered and rules and specifications relating to scaffolding activity are considered in coding rulesets. To facilitate the development of rulesets and perform safety checks, the following rules and regulations, and algorithms were adopted and discussed.

- *Minimum distance between Scaffold and building*: According to OSHA's handbook Subpart L, the maximum allowable distance between scaffold and construction work is 360 mm unless guardrails have been provided on the side of the scaffold facing the work. The algorithm for the execution of this rule after conversion to a machine-readable ruleset is shown in Fig. 4.
- *Minimum height between two platforms*: According to the CPWD handbook, the minimum distance or clearance between the platforms meets the design criteria. According to the OSHA 1926 Subpart L handbook, the minimum distance has to be 2.5 m or 2500 mm between two platforms to qualify free from any risks and provide enough *headroom* to work. The clearance should always be greater than this value for a safe and efficient workflow. The minimum distance parameter is provided in the ruleset dialog box as shown in Fig. 5.
- *Minimum height of Toe boards*: According to the IS Code, the minimum height of each toe board has to be greater than equal to 150 mm for it to be considered

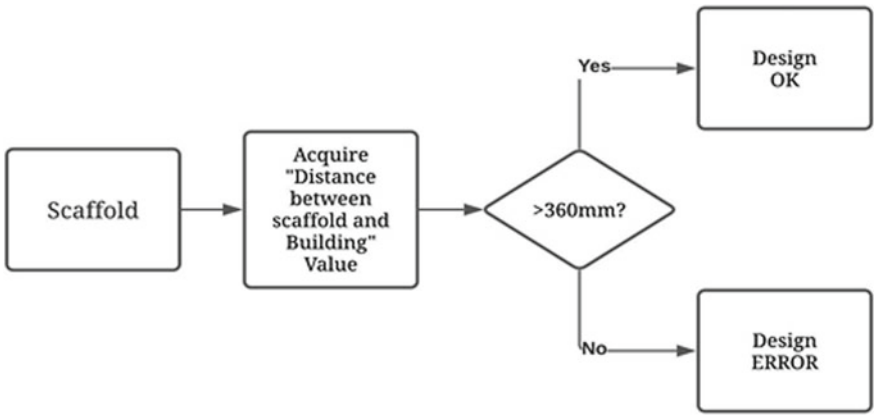

Fig. 4 Algorithm of ruleset for checking distance between scaffold and building

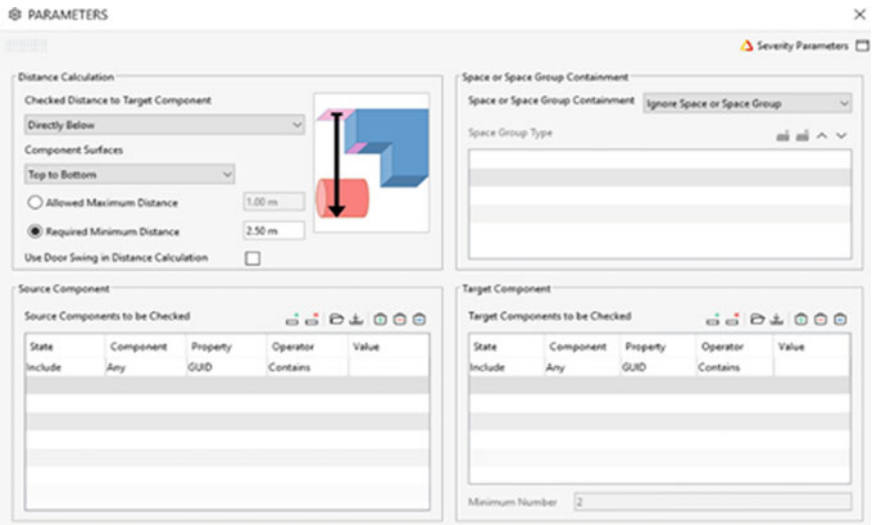

Fig. 5 Dialog box for defining parameters for rulesets

not to pose any safety risks. The algorithm is developed to check whether toe boards are provided or not in every instance of the scaffolds as shown in Fig. 6. The necessity of toe boards is not only to protect falling off equipment and hitting bystanders but also unexpected slippages of workers on the platform that may lead to trapping or fall.

- *Minimum height of the guard rails*: According to OSHA's handbook Subpart L and Indian Standard Codes, the minimum distance or clearance between the platforms has to be 2.5 m or 2500 mm to qualify free from any risks and provide enough

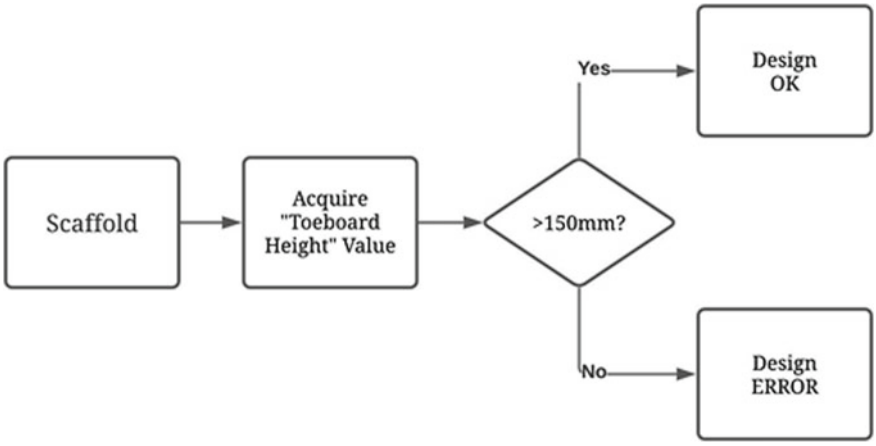

Fig. 6 Algorithm for checking toe boards

headroom to work. The algorithm for checking the height of guardrails is shown in Fig. 7.

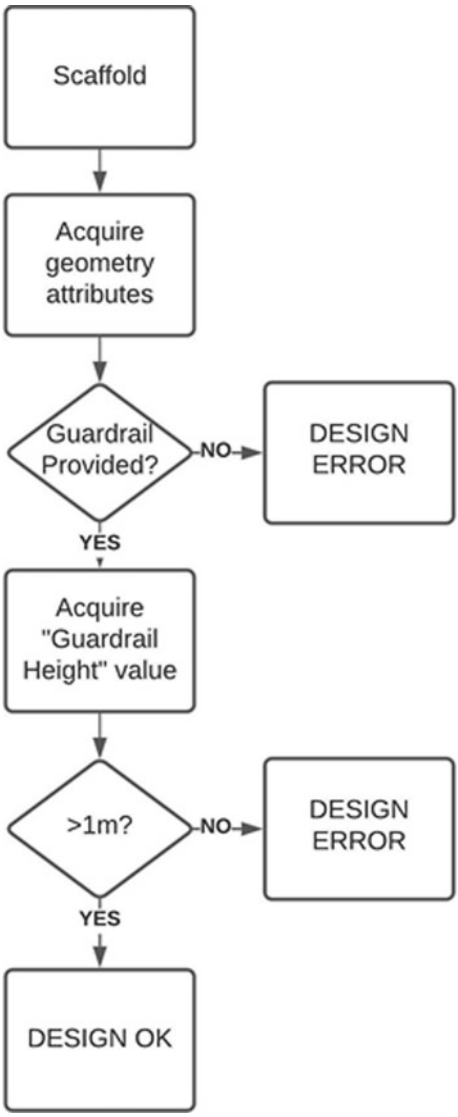

Fig. 7 Algorithm for checking height of guardrails

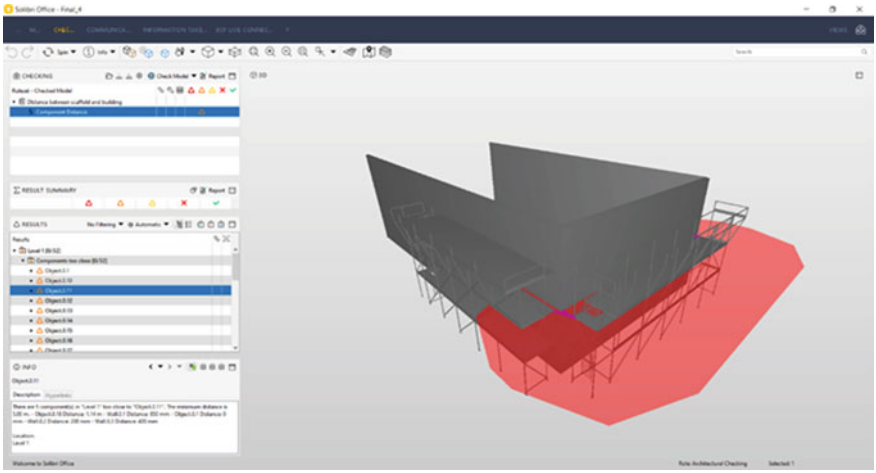

Fig. 8 Error showing insufficient distance between the scaffold instance and structure

4.3 Implementation and Execution of Rules

After developing the rulesets using the algorithms, the models have to be imported into a model checking software to check for their safety compliance. Proprietary software such as Solibri was used to facilitate automatic model checking. The developed models were visualized and evaluated for quality, integrity, and physical safety. The developed rulesets and 3D BIM model were imported into Solibri and safety checks were performed using the Model checker tab in the software. The rulesets checks if the imported 3D BIM model complies with the rules and identify elements where the change in design or modifications are required as shown in Fig. 8. The identified areas of non-compliance were represented as red zone and the violating distance was shown in highlighted pink markings. In addition to the visual information, a description box representing identified errors was shown in the model.

Safety checks such as compliance with guardrails, minimum platform clearance, and toe boards were also performed and shown in Figs. 9, 10, and 11 respectively.

The process repeats repeated till the model is completely verified. Finally, a report was generated showing every instance of potential safety risks associated with the scaffolds shown in Fig. 12.

4.4 Model Correction

The errors identified through the model checking software were exported as pdf file and the original 3D model is reviewed. Necessary modifications such as a change in dimensions, height were performed for every instance of safety non-compliance and

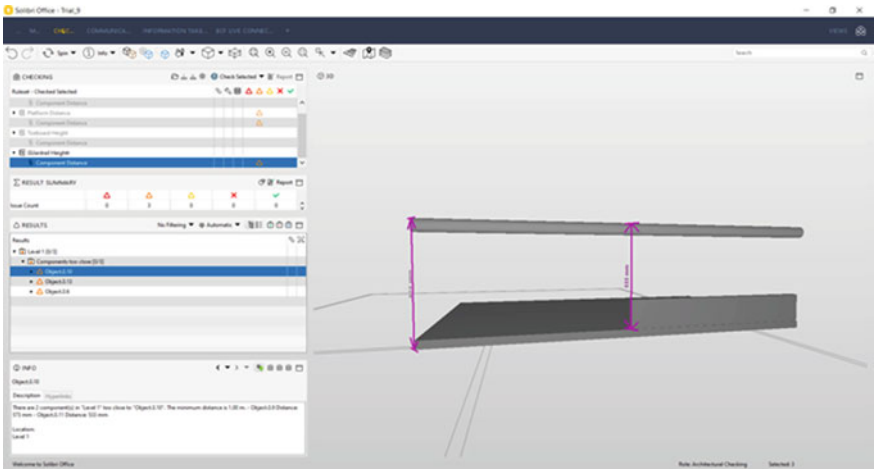

Fig. 9 Error showing insufficient guardrail height

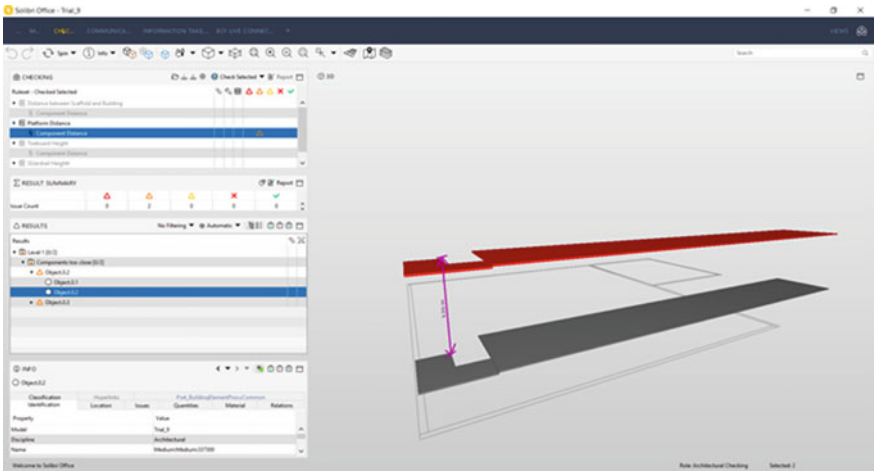

Fig. 10 Error on minimum platform clearance between multiplatform scaffoldings

the newly developed models were checked for safety in the model checker iteratively until no errors were identified as shown in Fig. 13. This enabled identifying and eliminating safety errors during the design stage of the project and the modifications made were communicated with the safety manager for future references.

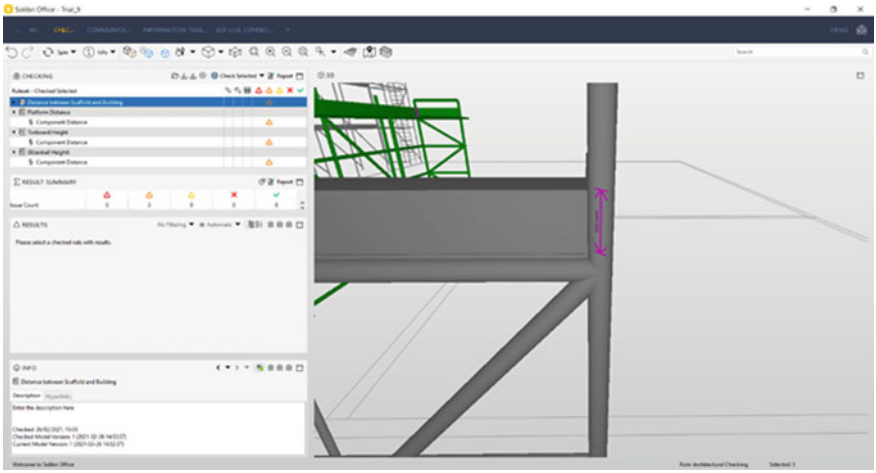

Fig. 11 Error showing insufficient toe board height

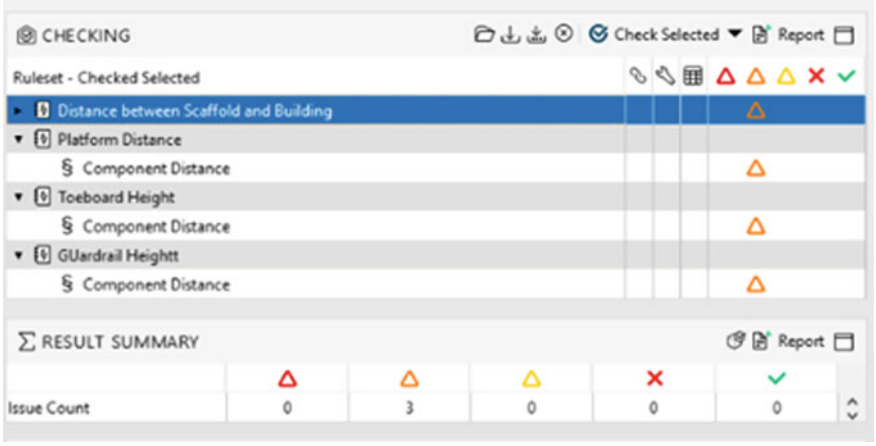

Fig. 12 Ruleset box indicating errors in the model

5 Discussion

It is identified that the scaffolding for a building requires different safety regulations and is required to be maintained during the construction stages. It is quite evident that different safety requirements need to be met to provide a safe working environment. The integration of BIM with safety management helps this process become relatively easier, less cumbersome, and allows performing the safety check requirements and developing a suitable safe design of scaffoldings for the project. The developed integration allows preventing accidents such as the risk of falling from heights, injuries

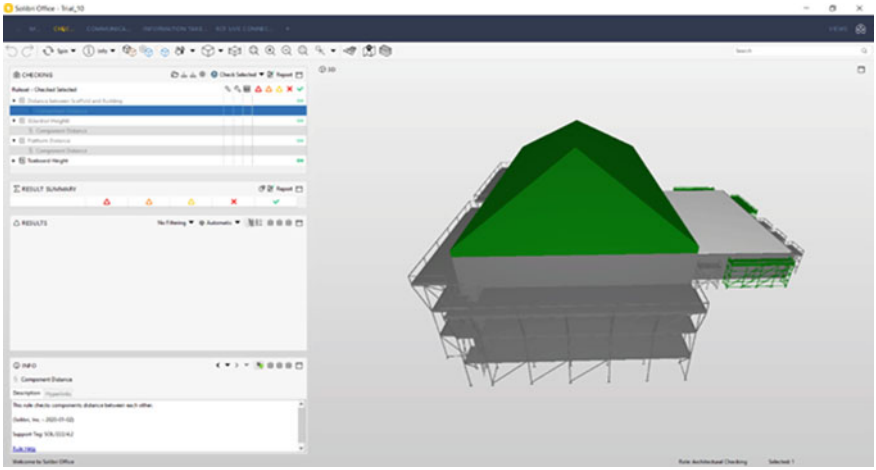

Fig. 13 3D model after elimination of errors in the design

due to improper clearance, and injuries due to getting hit by objects falling from a height in the construction site.

6 Conclusion

This chapter discussed the study conducted in India that develops a rule-based safety checking system for the safety planning of scaffolding by integrating BIM and safety management. The rules and regulations specified in the safety handbooks of CPWD, OSHA, and standard code of practice for safety were considered in developing a rule-based safety checking system. BIM models of building and scaffolding were developed and were integrated with the rule-based system and any associated safety risks were identified. This enabled identifying safety risks in scaffolding during the design stage of the project and allowed making necessary modifications before the start of the construction process. The results indicate the capabilities of automated safety rule checker for its practical applications in modeling and protection against various safety risks in scaffolds.

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A Comparative Study on Scholars' Perspectives on Factors That Affect Safety Awareness

Rita Yi Man Li

Abstract Unsafe behaviour and a lack of safety awareness are critical factors that cause accidents. This study reviewed journal papers on safety awareness in various industries, food, passengers, laboratories, and patients. Among the few databases, Web of Science and Scopus recorded the most articles, followed by Emerald, Science Direct, Taylor & Francis, Oxford, and Cambridge. The geographical distribution of journal publications about safety awareness was also investigated in this book chapter. Most articles, according to the findings, were produced in China. The US and the UK shared second place, followed by Korea and Australia. Most individuals claimed that safety education and training were crucial elements that affected safety awareness. This study offered suggestions to safety officers when they design and implement safety plans. It also offered hints to researchers who would like to research this area.

Keywords Safety awareness · Web of Science · Scopus · Construction industry · Manufacturing · Traffic and health

1 Introduction

Safety awareness is a kind of psychological alert in response to various external environmental conditions that may cause harm to themselves or others in their production activities. A lack of safety awareness is one main reason that leads to accident. Nevertheless, safety awareness levels are different among different workers. For example, as compared to experienced workers, new workers often come across accidents because they do not know on-site hazards and "do not know" explains 38% out of construction "over-3-day injuries". Safety awareness of the personnel working on decoration, repair, and maintenance projects is lower than those who work for a new skyscraper construction (Li et al., 2019). To raise the importance of safety awareness

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and reduce accident compensation, this book chapter mainly focuses on different factors that affect safety awareness.

2 Literature Review

2.1 Safety Awareness in the Construction Industry

There are different aspects of safety awareness. For example, in the aircraft manufacturing environment, Nektarios et al. found that workers preferred productivity rather than safety, and the length and type of employment influenced some attitudes towards the effects of safety awareness. The larger organisation resulted in more frequent safety communication than the small one, and the workers with shorter employment and the full-time contract impacted the safety more. Mudan (2018) conducted a questionnaire survey on workers of different types of work on a construction site in China. The results showed that organisational safety climate affected individual safety behaviour and awareness. Besides, a positive safety climate contributes to individuals' safety awareness and behaviour. Thus, strengthening the relationship between individuals is beneficial. Tadesse et al. (2016) conducted experimental tests, and structured questionnaires were used to collect data from workers in Ethiopia. The results showed that workers who served longer could have higher safety awareness. It was also related to the presence of workplace safety regulations. Another important finding was that employees' satisfaction towards their jobs, the relationship between workers, and educational attainment level could affect safety awareness.

2.2 Passenger Safety Awareness

Chang and Liao (2009) examined the relationship between aviation safety education and cabin safety awareness of airline passengers. The finding was that aviation safety education could promote safety awareness. Moreover, it depended on the passenger's attitude to learn aviation safety. Lu et al. (2018) used survey data from 316 ferry passengers in Hong Kong and found that safety marketing could positively promote passengers' safety awareness and change safety behaviour. The main safety marketing incentives include the provision of equipment, promotion, improvements in place and service, and these are the valuable criteria for ferry operators to evaluate their safety operations.

2.3 Food Safety Awareness

Two hundred forty household food preparers were randomly selected from Punjab and asked about their food safety awareness in the study of Sonika and Jasvinder. The result showed that the higher the respondents' education level, the higher their consciousness of food safety. Besides, the increased family income of household food preparers had a higher safety awareness score. Bektas et al. (2011) investigated the level of food safety awareness among consumers in Turkey. It showed that people aged 50 and above have higher food safety awareness.

2.4 Safety Awareness in the Laboratory

Celina et al. examined the Physics laboratory safety awareness attitudes among students at Mindanao University of Science and Technology (MUST). They modified the former questionnaire from another university with four considered factors: status of the risks they encountered in the Physics laboratory; the state of preventive measures the students have taken to avoid risk; gender of the respondents, and the department where the students belong. The results showed that Chemistry and other sciences laboratory classes can strengthen students' safety awareness. Walters et al. (2017) studied safety awareness, attitudes and practices in chemical laboratories of students at the University of Trinidad and Tobago. It turned out that safety awareness, beliefs and practices could influence each other. To improve students' awareness, students' attitudes should reinforce, and safe practices should increase.

2.5 Patient Safety Awareness

After attending the safety skills training programs, participants reported more vibrant and detailed observations indicating a more in-depth understanding, awareness and analysis of workplace safety issues. The safety awareness after attending courses was significantly improved.

3 Research Method

3.1 Content Analysis of Journal Articles

Many people have studied "safety awareness" in different aspects, this study collected journal articles from the various academic websites—Web of Science, Scopus,

Table 1 The results of data collection in database

The academic website	The numbers of articles that the website contained	Number of relevant articles
Web of Science	8,295	8
Scopus	16,134	7
Science Direct	4,102	4
Cambridge	6,219	0
Oxford	61,995	1
Taylor and Francis	160,142	2
Emerald	20,000	3

Science Direct, Cambridge (Core. Cambridge Journals), Oxford (Academic Journals), Taylor and Francis, Emerald. It searched the articles by using keyword "safety awareness", and the relevant journal articles were chosen. Similar content on the same topic is grouped in this research. Phrases that always appeared together for factors that affect hazard awareness are parsed by tokenisation, similar to Li et al. (2019) and Li et al. (2022).

4 Results

There are 25 articles that meet all the requirements. We can see in Table 1 that an enormous number of articles were obtained from "Taylor and Francis" with 160,142 articles, followed by "Emerald" and "Scopus". Nevertheless, "Web of Science" had the highest numbers of relevant articles and "Scopus" placed number two, "Science of direct" ranked number 3. Although Cambridge recorded 6,219 results, the final relevant articles in Cambridge was 0. The numbers of articles found in different academic websites and the final relevant articles are shown in Table 1.

4.1 Factors Affecting Safety Awareness

Table 2 concluded the factors that affect different types of safety awareness in different industries. Moreover, the degree of importance is directly proportional to the number of articles. Five (20%) articles research on the safety awareness in industry and followed by food safety awareness with four (16%) articles, safety awareness in laboratory with three (12%) articles. Many of these suggested that training and education were important factors that affected safety awareness.

Table 2 Factors that affect safety awareness

Types		Citations	Country	Factors that affect safety awareness
Safety awareness in the industry	Aircraft manufacturing environment	Nektarios et al.	Australia	***The length and type of employment*** had a certain impact on the attitudes of human factors on safety awareness
	Construction workers	Fung et al. (2016)	China	The perceived usefulness of safety measures strongly influenced the degree of safety awareness
	Construction industry	Mudan (2018)	China	***A positive safety climate*** contributed to individuals' safety awareness and behaviour, thus strengthening the relationship between individuals
	Manufacturing industry workers	Tadesse et al. (2016)	Ethiopia	The ***workers who served longer*** could have higher safety awareness It was also related to ***the presence of workplace safety regulations*** Another important finding of this study was that ***employees' satisfaction towards their jobs***, ***the relationship of workers*** and ***level of educational attainment*** could affect safety awareness
Safety awareness in the industry	Construction industry	Ghosh (2014)	America	FDHMs helped facilitate ***interaction between project participants,*** and this interaction also helped them better understand the project, which had a positive impact on their safety awareness. Therefore, the meetings might positively impacted workers' safety awareness
Passenger's safety awareness	Safety awareness in passenger cabin	Chang and Liao (2009)	Taiwan, China	***Aviation safety education*** promoted passengers' safety awareness in the airline passenger cabin. Moreover, the degree of this safety awareness depended on the attitude of passengers towards aviation safety education
	Passenger's behaviour in the ferry	Chin et al. (2018)	Hong Kong, China	***Safety marketing stimuli*** positively affected passengers' safety awareness and accelerate safety behaviour changes. The main structures of safety marketing incentives included equipment, promotion, place and service, and these were valuable criteria for ferry operators to evaluate their safety operations

(continued)

Table 2 (continued)

Types		Citations	Country	Factors that affect safety awareness
Safety awareness in the laboratory	Safety awareness in the laboratory	Celina et al.	Pilipinas	Students' safety awareness of laboratory could be enhanced by their ***Chemistry and other sciences laboratory classes***
	Safety awareness in the laboratory	Ayana et al. (2017)	Trinidad and Tobago	Safety awareness, ***attitudes and practices*** were all connected and could influence each other. To improve student's awareness, the attitudes of students should be reinforced and the safe practices should be increased
	Safety awareness in microbiology Laboratory	Hogan et al.	America	The micro lab could increase their safety awareness by ***tracking errors in real time*** and ***using a standardised process*** that involved timely follow-up, technologists were educated on error prevention
Food safety awareness	Food safety awareness	Caroline et al.	UK	***The Watch-and-Click tool*** could positively add to the range of existing methods for eliciting and improving food safety awareness
	Consumer awareness about food safety	Bektas et al. (2011)	Turkey	Increasing ***the levels of education and welfare*** could improve food safety awareness ***The presence of individuals at the age of 50 and above*** in a house increases family food safety awareness
Food safety awareness	Food safety awareness	Sonika and Jasvinder	India	***The respondents' background*** affected their awareness regarding food safety
	Food safety awareness	Roberts and Deery (2004)	Australia	***Implement effective education and training programmes; provide information; timely review of food safety projects***; and ***risk-based inspections*** increased the level of safety awareness
Patient's safety awareness	Patient's safety awareness among surgeons	Arora et al. (2012)	UK	***The safety skills training*** significantly enhanced surgeons' safety awareness
	Patient's safety awareness among surgeons	Nwosu et al. (2019)	Nigeria	The ***surgeon's professional status and working experience*** influenced patient safety awareness among surgeons in Enugu

(continued)

Table 2 (continued)

Types		Citations	Country	Factors that affect safety awareness
	Patient's safety awareness of healthcare workers	Al-Mandhari et al. (2016)	Oman	***Workers' age and workplace*** indirectly related to workers' awareness and practice
Others safety awareness	Characteristics of safety communication network	Korkmaz and Park (2019)	Korea	***The safety communication density of each team*** played a significant role in determining the level of safety awareness and behaviour. Team members with good relationships exhibited better levels of safety awareness and behaviour
	Blood donors safety awareness	Bogdanovic (2006)	Republic of Serbia	***The gender*** and ***age of donors***, ***the times who donated blood*** and ***the educational level*** were related to blood safety
	Skin care safety awareness	Palmer and Freegard (1996)	UK	More commonly, those with skin problems had a higher safety awareness on skincare
	Women with diverse disabilities	Rosemary et al.	America	Most of the respondents expressed that ***disability-related safety awareness information*** was the essential material in the class, and it improved their safety awareness knowledge
	Fisher's safety awareness	Binkley (1991)	Canada	Fisher's safety awareness came from: ***education training in courses, government and company demonstrations, union activities, and have had a severe accident or having seen a fellow crew member seriously injured or killed***
	Cleaning workers' safety awareness at hospital	Arab et al. (2016)	Iran	The higher ***education level*** of workers tended to have stronger safety awareness The effect of ***training cleaning workers*** had strong impact on safety awareness
	Safety awareness in coal mine industry	Jiang et al. (2019)	China	***The safety management system*** directly affected safety awareness, and ***the safety culture*** indirectly affected safety awareness
	Marine safety awareness	Kang et al.	Korea	***Definitive traits*** had a positive effect on marine safety awareness, while ***marine safety incident prevention*** as well as ***behavioral and definitive traits*** had a positive effect on marine safety attitudes

Table 3 Countries' research on safety awareness

Country	Safety awareness in the industry	Passenger safety awareness	Safety awareness in the laboratory	Food safety awareness	Patient safety awareness among surgeons	Others safety awareness	Total
Australia	1	–	–	1	–	–	2
China	2	2	–	–	–	1	5
Ethiopia	1	–	–	–	–	–	1
America	1	–	1	–	–	1	3
Pilipinas	–	–	1	–	–	–	1
Trinidad and Tobago	–	–	1	–	–	–	1
UK	–	–	–	1	1	1	3
Turkey	–	–	–	1	–	–	1
India	–	–	–	1	–	–	1
Nigeria	–	–	–	–	1	–	1
Oman	–	–	–	–	1	–	1
Korea	–	–	–	–	–	2	2
Republic of Serbia	–	–	–	–	–	1	1
Canada	–	–	–	–	–	1	1
Iran	–	–	–	–	–	1	1

4.1.1 Countries' Studying on Safety Awareness

Fifteen countries were included in these articles. The level of safety awareness in a country can be known from its publication numbers. The more published articles about safety awareness, the more they pay attention to it.

Table 3 indicates most of the journal articles about safety awareness were published in China, which took part in 20%. The next is America and the UK, both of them had 3 articles which occupy 12%. Korea and Australia rank tied for third and account for 8% of the total articles. The fewest numbers of articles were published by authors from Turkey, India, Nigeria, Oman and other countries.

4.1.2 Year-Wise of Publication Articles

The year-wise measure of publication is one of the critical indicators to assess the year-wise degree of publication's growth and find that the most productive year of publication was in 2019 (Fig. 1).

The figure shows the number of journal articles published in different databases over 28 years from 1991 to 2019. The year 2019 was the most productive year in which

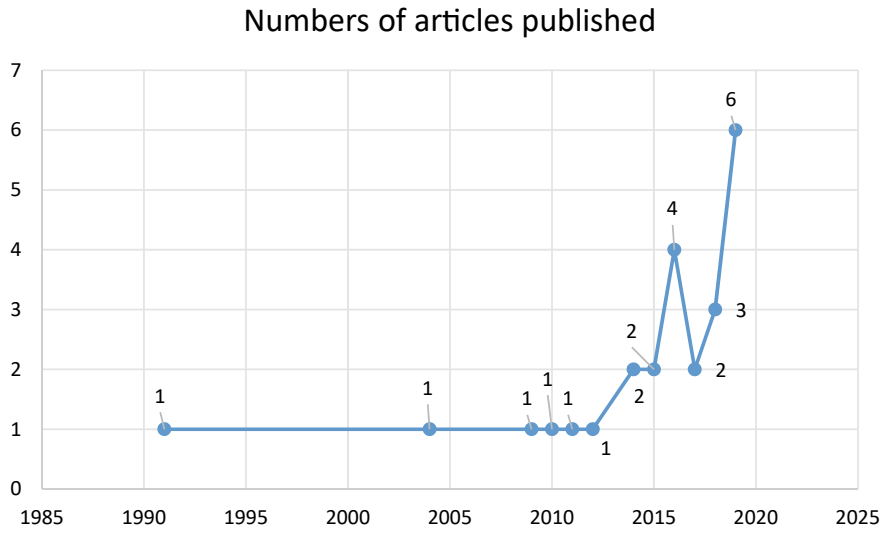

Fig. 1 Year-wise of publication articles

6 (24%) articles were published—followed by the subsequent highest publications of 4 (16%) in the year 2016 and minimum articles in the year 1991, 2004, 2009, 2010, 2011 and 2012 in which "1" (4%) article about safety awareness published.

4.2 Tokenisation Results

To analyse and conclude the factors affecting safety awareness, Table 4 shows the highest frequency factors affecting safety awareness types. It was found that the highest number of mentioned factors were psychological conditions. Many of the laboratory safety awareness research were related to CIIT, an independent human health research institute that studies chemicals' biological effects.

5 Findings and Discussion

As a result of the systematic analysis of data for the present study, below were some facts about "safety awareness" in journal articles published on different databases.

a. There was no relevant article on "Cambridge". There were eight articles published on "Web of Science" and followed by "Scopus" with seven articles, "Science of Direct" with four articles. Meanwhile, "Taylor and Francis" recorded the highest results of articles. When "Taylor and Francis" were searched with keywords of

Table 4 Tokenisation results regarding factors that affect safety awareness

Safety awareness in the industry (e.g. construction)	Count	Passenger safety awareness	Count	Laboratory safety awareness	Count
Psychological conditions	5	Aviation safety education	2	Safety awareness	4
Safety awareness	5	Safety marketing stimuli	2	CIIT and CEA students	2
Hazard awareness	4	Attitude consistency	2	CIIT and CEA	2
Odds of hazard awareness	3	Aviation safety	2	CAS students	2
Odds of hazard	3	Marketing stimuli	2	CEA students	2
Physical working environment	3	Safety awareness	2	Present findings	2
Physical working	3	Safety education	2		
Safety climate	3	Safety marketing	2		
Safety measures	3				
Workers awareness	3				
Working environment	3				

Food safety awareness	Count	Others safety awareness	Count
Food safety	12	Safety awareness	13
Mean awareness	3	Average score	11
Safety awareness	3	Marine safety	7
Case of service class	2	Safety points	6
Probability of having knowledge	2	Awareness and behaviour	5
Sensitivity to food safety	2	P-value	5
Service class as compared	2	Strong safety awareness	4
Annual family income	2	Cleaning workers	4
Case of service	2	Positive effect	4
Class as compared	2	Significant difference	4
Click response data	2	Strong safety	4
Food safety awareness	2	Safety awareness among workers	3
Higher mean awareness	2	Safety awareness and behaviour	3
Sensitivity to food	2	The score of having strong	3
Watch and click	2	Strong safety awareness among	3
Annual family	2	Awareness among workers	3
Business class	2	Groups p value	3

(continued)

Table 4 (continued)

Food safety awareness	Count	Others safety awareness	Count
Click response	2	Safety awareness among	3
Family income	2	Among workers	3
Higher mean	2	Awareness among	3
House increases	2	Become aware	3
Response data	2	Condition score	3
Service class	2	Definitive traits	3
		Groups p	3
		Safety communication	3

"safety awareness", the results displayed 160,142 articles. The next majority was "Emerald" and "Scopus".

b. The study also researched the geographical distribution of journal articles about safety awareness. The results revealed the highest number of articles in China. The US tied with the UK for second place, Korea and Australia ranked third. Turkey, India, Nigeria, Oman, and many other countries had the least number of articles. Thus, China could be regarded as the most safety-conscious country globally.
c. This study researched on year-wise publication of articles about safety awareness in a different database over 28 years from 1991 to 2019. The results showed that 2019 was the most productive year, followed by 2016, the least productive year was 1991, 2004, 2009, 2010, 2011 and 2012. In general, the published articles about safety awareness maintained an upward trend and people were getting more attention on safety awareness.

6 Conclusions

In today's society, safety awareness could determine someone's safety behaviour and then affected others around. Research on safety awareness ranged from safety awareness in the industry and laboratory, food and passenger safety awareness, and other kinds of safety awareness. Although articles about safety awareness are published from countries worldwide, China had a lion share in this field.

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Hazard Awareness in Property Refurbishment Work: An Analysis on Court Case Precedents

Meilin Ding and Rita Yi Man Li

Abstract Due to the absence of the original building plan, low foreseeability and work environment uncertainty, workers do not have time to read building structure documents and specific work requirements and underestimate the complexity of the work; working for a refurbishment project is not safer than that for a new building. This study reviewed the construction accidents court cases in refurbishment and demolition work in Hong Kong from 1990 to 2019 in the legal databases Westlaw Asia and LexisHK. It found that some victims preferred to take risks, indicating low hazard awareness, while others were ignorant and did not know the causes of the accidents even after their injuries. Furthermore, many employers' hazard awareness is low because they do not aware of hazardous areas. Some supervisors did not instruct their employees to use the protective equipment even though it is provided. As we may some construction sites have already utilised robots with weak artificial intelligence, this article raised a futuristic question regarding the hazard awareness responsibility of autonomous robots with strong artificial intelligence.

Keywords Property refurbishment · Hazard awareness · Court case · Hong Kong

1 Introduction

Obsolescence is a threat to the market value of old buildings. Compared to new buildings, old buildings require higher operational costs due to the latter's lack of efficient electrical appliances and deficient design (Trabucco & Fava, 2013). This showcases the economic value of refurbishment: the increased market value resulting from renovation usually outweighs the cost (Li et al., 2019a, 2019b).

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Refurbishment works are fragmented but specialised with specific requirements. For workers involve in refurbishment works, this challenging field needs extensive knowledge, accurate forecasting, careful planning and sound decisions to make adjustments quickly Strank. However, it is far from easy despite high expertise requirements due to limited budget, tight schedule, and other quality issues (Aiste Mickaityte et al., 2008). Renovation works are complex and uncertain, often difficult to meet customers' demands and environmental friendly requirements at the same time. When workers refurbish a building, it is necessary to minimise costs, ensure safety, reduce energy consumption, and encourage the implementation of other sustainable refurbishment principles (Aiste Mickaityte et al., 2008). To satisfy the occupant's indoor environment and energy performance, factors such as temperature, lighting, air quality, noise management, and access to views need to be considered (Thomas, 2010).

While poor site safety has resulted in deaths and injuries (Li & Poon, 2011), many people consider building refurbishment the most notorious and hazardous sector activity of the construction industry (Douglas, 2006; Gorse, 2009). Furthermore, refurbishment possibilities are higher than demolition and rebuilding due to the ever increase in population and the demand for better living and the sustainability of ageing buildings. These are in sharp contrast to the concerns regarding the costs and time involved in refurbishment works (Mourão et al., 2019). Besides, these projects may involve more stakeholders than new building works. For example, the site occupants may still live there when the project occurs. Moreover, the workers may have to demolish the existing parts or components.

Given the popularity of refurbishment of ageing properties and an increasing number of casualties involved in such projects, it is necessary to research this area. We attempt to study various factors that affect occupational safety in renovation works by analysing the court cases on property refurbishment.

2 Research Method

This article analysed property refurbishment court cases in Hong Kong from Westlaw Asia and Lexis Hong Kong. Keywords search included construction accidents, refurbishment accidents, safety awareness, and personal injuries.

Despite the relatively scarce court cases addressing construction workers' safety awareness in refurbishment works, this review aimed to review some typical court cases in Hong Kong to give readers a clearer picture of refurbishment-related accidents that gave rise to court involvement.

Currently, many journal articles analysed the laws and regulations related to occupational safety and the health system, as shown below. This study found that studies utilising court cases in occupation safety and the health system, especially those is based in Hong Kong, remained limited (Table 1).

Table 1 Journal articles' topic on occupational safety and health

Topic on occupational safety and health	Name of the journal article	Year of publication	Name of the author
Court cases	Workers' compensation for non-fatal construction accidents: review of Hong Kong court cases	2009	Li and Poon (2009a, 2009b)
	Accidents in Malaysian construction industry: statistical data and court cases	2015	Chong and Low (2014)
	Safety, courts and crime: occupational safety and health prosecutions in the magistrates' courts	2016	Johnstone (2003)
Online information and information technology	An informal institution comparative study of occupational safety knowledge sharing via French and English Tweets: languaculture, weak-strong ties and AI sentiment perspectives	2022	Song et al. (2022)
	Economic development and construction safety research: a bibliometrics approach	2022	Luo et al. (2022)
	A knowledge-based approach for enhancing fall prevention in the construction industry	2020	Chellappa et al. (2020)
	Construction safety informatics	2019	Li (2019)
	Sustainable construction safety knowledge sharing: a partial least square-structural equation modeling and a feedforward neural network approach	2019	Li (2019)
	How does facial recognition as an urban safety technology affect firm performance? The moderating role of the home country's government subsidies	2021	Shao et al. (2021)
	An economic analysis on automated construction safety	2017	Li (2017)
	Construction safety and waste management	2015	Li (2015)
	Construction safety	2013	Li and Poon (2013)

(continued)

Table 1 (continued)

Topic on occupational safety and health	Name of the journal article	Year of publication	Name of the author
	Using Web 2.0 to share knowledge of construction safety: the fable of economic animals	2011	Li and Poon (2011)
Worker	Layers of vulnerability in occupational safety and health for migrant workers: case studies from Canada and the UK	2016	Sargeant (2016)
	The occupational safety and health rights and workers' compensation entitlements of illegal immigrants: an emerging challenge	2016	Guthrie (2005)
Law/Regulations/Legislation	Enforcement of occupational safety and health regulations in Nigeria: an exploration	2014	Umeokafor et al. (2014)
	The designer's role in workplace health and safety in the construction industry: post-harmonised regulations in South Australia	2015	Bong et al. (2015a, 2015b)
	Construction industry prosecution cases under Malaysian occupational safety and health legislation	2017	Razak et al. (2017)
	Briefing: occupational safety and health regulations in Oman	2018	Umar et al. (2018)
	Noncompliance of the occupational safety and health legislation in the Malaysian construction industry	2019	Hamid et al. (2019)
	Ranking of risks for existing and new building works	2019	Li et al. (2019a, 2019b)
	Dynamic panel analysis of construction accidents in Hong Kong	2017	Li et al. (2017)
Robotics	Robot application and occupational injuries: are robots necessarily safer	2022	Yang et al. (2022)
System	Occupational safety and health management systems in Australia: barriers to success	2003	Gallagher et al. (2003)

(continued)

Table 1 (continued)

Topic on occupational safety and health	Name of the journal article	Year of publication	Name of the author
	An overview of the occupational safety and health systems of Nigeria, UK, USA, Australia and China: Nigeria being the reference case study	2015	Abubakar (2015)

As there is a lack of research in this area, it is hoped that the present study fills the knowledge gap. The research may also contribute to property management and refurbishment sectors and offer insights for those who implement compensation and safety policies.

3 Results

3.1 Individuals' Hazard Awareness

Individual workers' low safety awareness and their colleagues' negligent acts may affect their behaviours (Lingard & Turner, 2017). Unsafe working conditions, poor workforce safety behaviours and a lack of safety knowledge may also affect hazard awareness and lead to accidents (Li & Poon, 2009a, 2009b). However, it is reasonable that construction workers do not risk their lives under normal circumstances. If they are not under pressure from their senior or management, or occasionally from colleagues of the same trade or other trades, workers should follow established practices for their well-being, safety and occupational health. They have to follow the safety rules instructed by site managers that comply with relevant rules and regulations. However, a lack of awareness of the hazards and risks involved in construction is a problem (Barber, 2002). The following cases are relevant to these factors.

3.1.1 Lack of Adequate Safety Knowledge

In Ho Foon Cheung v Shun Yip Engineering Co. Ltd. [2011] HKCU 2157, the defendant hired the plaintiff as a painter to paint a wall on the roof. His work involved getting over the two parallel cylindrical air conditioning pipes across the roof. The plaintiff made an error judgement and stepped on the high and broad pipes with a convex surface, which were not designed or meant to be used as steps. He had not been told not to step on such pipes nor received relevant training to handle such a situation. He had formed the unsafe habit without being warned not to do so by his supervisor. Before the accident, he went to the roof every day to change his clothes. As he was familiar with the environment, this might lower his safety awareness. Without being warned, such hazardous activities eventually caused accidents.

3.1.2 Taking the Risk Voluntarily

Some people are aware of the safety risk, but they simply accept it. Others undertake hazardous activities because of laziness. In Lee Yam Kan v Ng Pui Kuen & Another [2016] 6 HKC 318, the plaintiff, as a scaffolder, suffered from industrial accidents and fell from a fence wall in demolition work. The plaintiff contributed 30% to the damages he suffered owing to his negligence. He chose to take the risk voluntarily and adopt his unsafe method because other options were more inconvenient, troublesome and time-consuming; he wanted to save himself from trouble. Alternatives left for the plaintiff included using lifting appliances directly or asking for his co-worker to assist him, which would be safer for him. Another consideration of the plaintiff was that he wanted to satisfy his boss. He chose to adopt his working method to work for his employer's business, believing that his boss would be unhappy if the unused or unnecessary bamboo poles were not removed from the house.

In HKSAR v China State Construction Engineering Corporation [1998] 2 HKC 612, the Labour Officer found a worker squatting on a water meter cupboard while inspecting the defendant's construction site. The magistrate argued that whether the defendant, the employer, expressly instructed the plaintiff, the employee, to work from the top of the cupboard or not was not relevant. The court held that construction companies should give more than lip service to the safety regulations. Besides, the defendant had 27 convictions and had a poor safety record in complying with safety regulations. Thus, there was no mitigating factor to be considered.

Even though employees might be prone to act carelessly due to tight schedules and a lack of professional knowledge, employers should adopt a proactive approach to protect employees' safety. As per Stokes v Guest, Keen and Nettlefold (bolts and Nuts) Limited, employers should apply their knowledge reasonably and prudently to protect workers' safety. Besides, the employer shall provide all workers with adequate information which is suitable and adequate on sites and prevent workers from falling from heights. In the Accident Report, the Labour Department recommended that more workers should be assigned to similar work.

Another perspective is that some employees may blindly follow what the majority do, violating safety rules, even though they previously received relevant training. In Lai King You v Acciona Infrastructures [2009] HKCU 670, the plaintiff, a metal worker alleged that he suffered deafness due to high noise levels in the workplace. Although he attended a safety training seminar before commencing work, he ignored the advice that ear muffs or earplugs should be used in a noisy environment. He thought he needed not to wear earplugs as most workers did not do so on construction sites. He believed that workers could withstand a certain noise level, and he stated that he was not aware of anybody who had suffered a mishap or adverse consequences from working in a noisy environment during his many years of work.

3.1.3 Employers Were Not Aware of the Hazard and Failed to Take Necessary Precautions

In Fung Shuk Fan Cinnie v Land Fortune Ltd [2007] HKCU 1282, the plaintiff, an Assistant Art Director, was requested to install spotlights along a portion of the edge of the rooftop, a restricted area with no fence and railing along the edge of the building, on top of several voids of different sizes. The accident happened when the employer was supervising the setup of spotlights. The Art Director stepped into one of the void openings and fell subsequently.

The court held that safety was the employer's responsibility rather than the Art Director's. The employer should have been aware of the hazardous working environment on the rooftop. No clear warning signs were placed around the voids, and no specific oral warnings had been given, nor were there any attempts to cover or fence off the voids. However, there were hazard notices on the ground, and the voids were painted in bright yellow colour. There was no evidence suggesting that she did not guard against unique risks that could have been incidental to it ordinarily for the plaintiff. The defendant, however, should have raised the safety awareness of the employees so that they would take elementary precautions.

In Ho Foon Cheung v Shun Yip Engineering Co. Ltd. (2011) HKCU 2157, the court suggested that no matter how experienced the employee was, the employers were duty-bound to take reasonable measures in assisting the employee on how he should carry out his work safely.

3.1.4 Res Ipsa Loquitur

Res ipsa loquitur refers to the fact that a plaintiff injured in an accident does not know the precise cause of the accident that has simply happened (Trindade & Feng, 2000). We may interpret this Latinism term as "the thing speaks for itself," which refers to the fact that the circumstantial evidence in an accident permits the inference that a defendant was at fault (Casey, 2020).

In Lam Shun Shing v Wang Ren Chu [2019] HKCU 785, the paint worker (the plaintiff) was standing on a wooden trestle ladder when a cord of hemp rope attached to the two legs of the ladder below the apex suddenly snapped. The ladder collapsed and caused him to fall onto the floor. Regarding the cause of the accident, there was no direct evidence showing the defective state of the ladder. Moreover, the claimant had used the ladder in the morning when the accident occurred, but no problem arose. The plaintiff stated that water on the waxed floor might have caused the ladder to slide outwards. It was later found that the waxing did not appear to be new.

The court applied the doctrine of res ipsa loquitur to seek compensation for the plaintiff. It found the collapse of the ladder was due to the sudden snapping of the hemp rope, and the accident would not have happened if the hemp rope had been in a good and durable condition to withstand the tension applied to it during normal or ordinary use of the ladder.

3.2 Getting Injured While Working in Collaboration with Co-workers

In Lam Fong and Ho Kok Keong v So Hoo Yuen [1990] HKCU 134, the fatal accident occurred when the plaintiff dismantled bamboo scaffolding while passing the short bamboo "putlogs". His seven colleagues worked on the scaffolding in a high position, then passed the putlogs down for binding poles. Without wearing a safety helmet or a seatbelt, he was hit by a "putlog" in his forehead when he looked up. The blow to his head caused him to fall to the ground, and he died because of the fall. The court held that the highest probability for the putlog to come to fall was that a dismantling worker negligently dropped the putlogs or had not properly secured it to a pole while passing it down. It was not simply because its position in the scaffolding was loose: the plaintiff's co-worker could have lowered his safety consciousness during the process.

In Ha Ka Hei v Decor One Design & Engineering Ltd. [2010] HKCU 1820, the plaintiff fell, hit his head and injured his eye and neck during demolition work. The plaintiff and his two co-workers stood on a 3-m-high working platform and lifted an I-beam. Unfortunately, the chain hoist fell off with the I-beam and hit the platform where the plaintiff stood. The plaintiff's working capacity was limited because of the incident and suffered a permanent loss of earning capacity. Apart from the renovation and refurbishment skills, he did not have other vocational training. The plaintiff's permanent and irreversible visual impairment rendered him unable to operate dangerous machinery nor work at height in a hazardous environment.

Despite limited court cases in this field, we can infer that collaboration among construction workers at work may not necessarily enhance safety at work. Workers may be hurt by their negligent co-workers who have low hazard awareness.

3.3 Extrinsic Safety Risk Factors

The existing factors that affect safety risks may be related to the safety laws. In Hong Kong, it comprises of Builders' Lifts and Tower Working Platforms (Safety) Ordinance, Factories and Industrial Undertaking Ordinance, Factories and Industrial Undertakings (Safety Management) Regulation, Occupational Safety and Health Ordinance, and Construction Sites (Safety) Regulations. The Construction (Design and Management) Regulations (2015) clearly state the responsibility of the parties, identify the potential hazards of health and dangers, and assess the relevant risks. These regulations aim to help contractors plan the work and use the correct information to evaluate the risks involved. The contractor must develop, implement and maintain adequate health and safety management procedures during the construction process (Howarth, 2001). Such requirements are within the scope of the 2015 Regulations and in line with other current legislation.

As early as 1950, Lord Oaksey provided his opinion on the employer's duty to provide a safe work system, method of operation, and a safe working environment. He believed that when the mode of operation is dangerous or involves many workers who have to perform different functions on sites, employers have to decide which system should be adopted. This view is confirmed in one of the recent court cases in Hong Kong. The court case of Li Moon Chai v Leung Shu Man [2008] HKCU 1377 concludes that an employer owes his employee a duty to exercise reasonable care to provide a safe system at work. For example, the court was not convinced that placing wooden planks could be used as safety equipment to facilitate walking or working.

It is hard to imagine that an employer not caring about work safety can provide a safe workplace system. Moreover, a safe work system should include devising such a system for its operation (Li & Poon, 2009b). Nevertheless, providing a safe system at work requires employers' high level of safety awareness. In the following section, this paper explores safety awareness issues among employers.

3.3.1 Work Safety System

The external factors are examined in two parts. The first part evaluates the safe work system and the second analyses safety management. A safe work system refers to equipment such as scaffoldings, safety helmets, safety belts, etc. Personal Protective Equipment (PPE) is a critical means to protect the wearer from worksite hazards (Md Ulang et al., 2014). Regarding safety management, a hierarchy of protocols and procedures are implemented to ensure that the construction companies meet the safety needs and requirements. To ensure a safe work system, general means for operating the systematic process of a task should be established. All the hazards should be identified and removed, and safe working machines and their operation manual should be provided before the work starts. To ensure that the client and contractors abide by the laws, construction companies failing to take appropriate safety precautions shall be prosecuted.

Under common law, employers owe their employees a duty of care to ensure safety at work and determine what safety precautions should be undertaken. Safety management should thus be conducted from the design stage through the entire operation process (Mills, 2001).

The work system should be reasonably practicable, safe and risk-free to the workers' health. To ensure the safety of a work system, the risk assessment should be conducted in advance to minimise the hazards in a project. The major considerations include identifying foreseeable risks, evaluating the severity of the hazard which may cause injury, and carrying out suitable precautions to protect the entire workforce (Howarth, 2001).

In Lee Yam Kan v. Ng Pui Kuen [2016] 6 HKC 318, the defendant breached his duty as he failed to have a working system to deal with the new or unnecessary bamboo poles left on the construction site. Under a proper working system, the employees should be instructed on how and when to move those poles out of the venue if any unnecessary bamboo poles were found. At the same time, the employer should supervise the employees to ensure that they follow the working system for safety.

In HKSAR v Hong Dau Construction Co. Ltd. [2018] HKCU 2182, a tower working platform (TWP) snapped into two, with one side detached from the central lifting cage and hurting a team of four Vietnamese workers. The TWP was designed to be used by workers to repair the plasters on the external wall during refurbishment work and not for transporting workers or materials to the workplace. There was a void between the TWP and the bamboo scaffolding, which could be a hazard. Objects might fall off during the passing of materials, and a worker might fall from height when crossing the void. Besides, the facility owner should have ensured that all the structural and mechanical components of the lift were kept in a proper state of repair and maintained correctly as of the date of the accident. About the TWP, the owner should have checked the nuts and bolts visually or by using a torque wrench. The employer failed to ensure that the system was practicable, safe and without health risks.

Metal fatigue is one leading cause of facility failure. A visible sign of paint cracks can be a good indicator. In HKSAR v Hong Dau Construction Co. Ltd. [2018] HKCU 2182, an expert opined that there could be a visible sign of paint cracks a month prior to the failure of the joints above before the accident. It takes time for the mechanism of fatigue to develop, so there must be signs evidencing such development. The workplace occupiers, where various employees were located, failed to ensure that the machine was reasonably practicable safe and that there were no health risks. The disaster was the result of the TWP being used excessively. The quality of the weld joints at the four sleeves were substandard, which reduced the fatigue life limit of the joints. In that case, the TWP was used for 17 months, meaning the loads on the right-side platform were repeated in sufficient cycles to reach the fatigue life limit. Professionals in the field estimated conservatively that at least one month had lapsed prior to the accident.

Failing to warn against the hazardous area and provide an alternative safe means is the second type of safety system problem on construction sites. In Lee Chun Mui v. Securicor Gurkha Services Ltd. [2008] HKCU 311, the plaintiff lost her footing, fell down the stairs and injured herself in the refurbishment work. Due to the renovation work at the employer's office, the plaintiff was requested to take a circuitous route from the reception counter to the control room, which required going through two uneven and coarse staircases. Her injury happened when the handrails at the first staircase were removed, and the steps were scrapped. Regarding the safe system at work, the employer failed to warn the parties concerned about the hazardous staircases and provide an alternative route.

3.3.2 Safety Management

Safety management and supervision by safety managers are essential to safety at work. For example, the employees' machinery and equipment require regular inspection, checking, and maintenance under different conditions.

However, supervision is not easy. The common duty of care owed to an employee by his employer generally requires the latter to take the time and trouble to identify, locate, obtain and provide the former with the best safety system commonly available at the time, and give explicit instruction on its proper use. The managers and the contractors need to assess the facilities' risks. These people are duty-bound to consider that the equipment given to the workers might cause injuries or health problems to its users. In brief, risk assessment is an essential process for employers to perform their duty of care to their employees. Construction managers and contractors should carry out due diligence before the construction work begins. Nevertheless, they may have a low level of hazard awareness, similar to that of front line workers.

In Lee Yam Kan v. Ng Pui Kuen [2016] 6 HKC 318, the court held that the defendant should inspect the site and conduct a proper risk assessment before the scaffolding works. If any risk of injury was identified during the inspection, the defendant should devise a feasible solution to minimise such risks. The defendant was not on-site when the accident happened, let alone undertaking any proper risk assessment. The defendant's absence from the site was due to the low priority of the project and less effort being put into the control of the refurbishment works (Egbu et al., 1998). Nevertheless, he was liable for negligence under the Occupiers' Liability Ordinance.

Weather can be an external factor challenging safety management. For example, accidents may happen on sites during foggy and humid weather, making glossy locations (such as the bamboo steps of scaffolding, a fence wall or a staircase) slippery.

Other safety management problems include providing safety equipment to workers but not requiring them to use it properly during work. For example, the workers' mere provision of more safety belts is not considered sufficient. A safety belt may have saved the victim from fatal fall in Lam Fong and Ho Kok Keong v So Hoo Yuen [1990] HKCU 134. The court rejected the first defendant's evidence provided on the number of safety belts. It is more probable that more than one or two safety belts were made available.

Rules need to be stated in on-site memos and implemented. In HKSAR v Hong Dau Construction Co. Ltd. [2018] HKCU 2182, although the site memo stated that workers were prohibited from climbing between the TWP and bamboo scaffolding, how the workers could go about the scaffolding was ambiguous and full of contradictions. The conviction is still valid because the court held that the site memo should be properly implemented and maintained to be conducive to efficiency, occupational safety, and health. The prosecution alleged that the convicted failed to develop a set of in-house safety rules to provide instruction for achieving safety management objectives at the site. The convicted failed to implement other measures properly.

Thus, managers should enhance their knowledge and make a good division of work. Both managers and workers should know more about the refurbishment process. Well-defined duties of the shareholders can be a good way to help. Property management work can be a rather extensive task given the integrated multiple duties during the work process (Egbu, 1999). Their responsibilities are essential during the planning, coordination and management stages. (*Occupational Safety and Health*

Table 2 Supervisors' responsibility on workers' safety awareness under courts

Court case	Conclusion
Lee Yam Kan v Ng Pui Kuen & Another [2016] 6 HKC 318	The supervisors must monitor the daily on-site operations and give timely instructions to prevent accidents
HKSAR v China State Construction Engineering Corporation [1998] 2 HKC 612	The supervisors should correct the unsafe behaviours instead of merely letting them be aware of the dangerous activities
Ho Foon Cheung v Shun Yip Engineering Co. Ltd. (2011) HKCU 2157	The supervisors should exercise no less care on the experienced workers than inexperienced workers

Management in Renovation and Maintenance Works for the Property Management Industry, 2006) Generally, the success of refurbishment work depends on the ability of the property management to ensure that the subcontractors undertake the project effectively and efficiently without default (Okoroh & Torrance, 1999).

According to the 2015 Regulations, the principal contractor should assess the nature of the work to identify the extent of the risk and the measures to be taken to eradicate the potential danger. Analysing the court cases allow us to know whether the workers understand the theories well and the way employers interpret them, rather than merely examining how perfect the theories devised are. Some of the examples are listed in Table 2.

4 Factors That Affect Hazard Awareness

Table 3 listed nine factors mentioned in the literature that affected hazard awareness of the employee, which depended on the workers themselves, their co-workers, supervisors, and the working environment. For the employee himself, it depends on the worker's willingness to learn safety knowledge, risk-taking behaviour and previous experience. For example, safety training can help improve hazard recognition skills to prevent injury and ensure operational safety on construction sites (Albert et al., 2020). Besides the interactions and communications between the worker and his co-workers, co-workers' attitudes towards the regulations are important factors that affect the hazard awareness of an employee. Their behaviours in safety rules compliance, such as wearing earplugs or a safety helmet, and the managers' site planning also matter. In Australia, the safety regulations under Workplace Health and Safety are harmonised to mitigate construction hazards (Bong et al., 2015a, 2015b). Lastly, fostering an environment of safety might foster employees to form long-term safety habits. Some experts opine that automation can be a solution to mitigating accidents and improving safety at work (Zhou et al., 2013).

Table 3 Factors that affect hazard awareness. Keyword search included construction hazard awareness/occupational hazard awareness in Taylor and Francis Database

Factors that affect hazards awareness	Literature
Safety education, training, and knowledge sharing	Albert et al. (2020), Enshassi et al. (2016), Hwang (2020)
Risk-taking behaviour/poor worker behaviour	Albert et al. (2020)
Previous experience	Albert et al. (2020), Fung et al. (2016)
Communication	Enshassi et al. (2016)
Physical working conditions	Fung et al. (2016)
Pro-active site safety planning	Enshassi et al. (2016)
Technology applications	Zhou et al. (2013)
Regulations	Bong et al. (2015a, 2015b), Umeokafor et al. (2020)
Safety climate, safety culture	Zhang et al. (2015)

5 Future Prediction

The rapid development of technology such as information communication technology, radio frequency identification, and virtual reality encourages sharing safety knowledge (Zhou et al., 2013). Communication is no longer limited to the physical space. However, due to uncertainties of the innovative technologies, the construction industry is reluctant to implement new ideas and utilise these advanced devices (Zhou et al., 2013).

Compared with their counterparts in the Web 1.0 era, present-day construction workers have a more flexible, convenient, and low-cost way to learn and share safety knowledge via Web 2.0 (Li & Poon, 2011). From the economists' perspective, construction safety knowledge is indivisible and non-excludable. It means that the amount of knowledge will not be reduced nor exclude people from its access. However, people may be less motivated intrinsically or extrinsically to contribute their knowledge as they may simply free-ride the existing resources (Li & Poon, 2011).

Furthermore, the development of Building Information Modelling technologies can help reduce cost and safety problems. It speeds up the decision-making process, assists in proactive site safety planning and increases efficiency in the communication process (Enshassi et al., 2016).

6 Conclusion

Refurbishment work is no easier than building a new one owing to an absence of the original building plan, a lack of time to read the structure documents, various

specific work requirements and underestimation of the level of complexity of the work. Individual workers' low safety awareness and their colleagues' negligent acts may affect their behaviours. To ensure the safety system at work, general practice for operating the systematic process of a task should be established. All hazards should be identified and removed, and safe working machines and their operation manual should be provided before the work starts.

Autonomous unmanned vehicles are often used on sites in Hong Kong, and robots are deployed for window panel installation. They are available in the market, and humanoid robots such as HRP-5P are also found in the construction industry. Therefore, the hazard awareness issues may extend to these automated machines. In Brown's case, for example, the truck's white trailer backlit by an overhanging highway sign and a bright sky led to an erratic event in which the hazard awareness capabilities of the Tesla's systems was evaded, causing the death of the driverless car's passengers (Casey, 2020). That prompts us to ask a new question about hazard awareness in the foreseeable future: will software companies of autonomous robots with strong artificial intelligence which can think and make decisions on their bear the responsibility if any accident happens, apart from the tradition that the hazard awareness problems should usually be borne by the contractors and/or employers of the construction works?

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Identification of Workplace Risks and Their Risk Assessment During Transmission Line Construction: A Case Study on Infrastructure Project in Nepal

A. K. Mishra, J. S. Sudarsan, and S. Nithiyanantham

Abstract The research was intended to, identify the possible hazards, preventive and control measures implemented and assess their effectiveness at work place. Kaligandaki Transmission corridor project was selected for the study. The Kaligandaki transmission corridor projects extend from Mygdi to Nawolparasi with construction of three substations at Dana, Kushma and Nawolparasi. The research was carried out by utilizing the data collected from the experience and knowledge of KII experts, local people and researchers field observations along with by asking the duly semi structured questionnaire with client, consultant, contractor's managers, officers, engineers and the workers. It was identified that mechanical and fall hazards were the most prevailing hazards during construction. Exposures hazards, biological hazards, chemical hazards and psychological hazards were also found at work place. The major cause of accidents was the lack of knowledge and skill along with carelessness of the workers. Other activities like scaffolding works, deep excavation, material transportation, lifting and assembling of towers parts were also found as the equally risky activities during the construction of transmission line. It was responded that the major health problem faced by the workers due to physical hazards was the back pain and wrist pain. Similarly due to chemical hazards most of the workers responded allergic as the main health problem they faced during construction. So the management commitment towards motivation, health and safety along with workers participation are essential for the success of the project. Prevention and control measures have to be plan as per the level of risk.

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Keywords Construction transmission line · Safety management · Workers · Risk

1 Introduction

Good Occupational safety and health (OSH) at the workplace increases employee morale and productivity. OHSAS defines the OSH as "Conditions and Factors that affect or could affect the health and safety of employees or other workers (including temporary workers and contractor personnel), visitors, or any person in their work place" (OHSAS 18,001:2007) (clause 3.12).

The construction industry is the second largest economic activity after agriculture generates a large number of employment in Nepal. The construction works include constructing, erecting, repairing and demolishing the building, civil engineering, and other similar structures. It also contains assembly and installations on-site of prefabricated components and building engineering services for example construction of hydropower projects, construction of transmission lines for power supply, construction of buildings, Roads, Demolishing the outdated structures etc. (Mishra & Shaykya, 2019).

Nepal is the mountainous country having large number of revers and rivulets. Most of the major rivers of Nepal are originated from mountains and are flows from north to south direction (Rimal et al., 2003). Because of availability of abundance of water resources and the mountainous geology Government of Nepal realizes that the economic growth is possible only from utilizing the available water resources (Upadhyaya, 2002). Despite of having the huge potential of water resources only less than 5% of water resources are utilized for generating the electricity till now. According to the Transmission System Development Plan of Nepal, (July 2018) GON has the plan to develop 15 GW in 10 years and around 40 GW in 2040. GON has made the policy to attract the investment from privet sectors in developing the hydropower projects (GON, 1992, 1994, 2018).

Construction industry is vulnerable in the Occupational hazards point of view. Since, Transmission lines are complex in nature covering civil, electrical, mechanical works and also most of the towers are located at difficult terrain it is most hazardous in nature until and unless the occupational hazards are proactively as well as up to some extent reactively mitigated (Pun, 2011). In under developed countries like Nepal, all the construction industries including the Transmission line projects are more hazardous than developed countries due to our primitive construction methods, low concern about OSH, and low level of safety cultures unless health and safety measures are planned and implemented (OSH, 2014).

Construction of Transmission line is very challenging and difficult since most of the transmission line towers are located on hilly areas. Due to difficult location, primitive methods of transportation of materials, primitive construction methodologies, reactive OSH approach, taking OSH as an unnecessary burden, unawareness towards health and safety, ignorance of OSH measures, absence of proper OSH policies, Transmission line project construction in Nepal is susceptible to potentially

dangerous conditions which affect the health and safety of all personnel involved in the construction of transmission line projects. The majority of projects do not publicly consider or plan for health and safety concerns, or they do so insufficiently and frequently neglect them (OSHA, 2015a).

Construction projects may use different technologies for construction of projects they may be labor based technology, capital based technology, or labor based equipment supported technology (Adhikari & Pandey, 2016). In case of Kaligandaki Transmission Corridor Project (KGTCP) labor intensive technology along with labor based equipment supported technology are used for construction of projects due to the difficult terrain and requirements of handling of heavy loads of equipment's. The labors involves in constructions activities are highly exposed to the potential occupational hazards namely falling hazards, stroke hazards, electric shock, biological hazards, chemical hazards, chemical hazards, psychological hazards over and under temperature, snake bites, isolated rock fall and possible landslide etc. (Purohit et al., 2018). Due to lacking of policy, planning and training, workers are exposed to high risk of accident, high potential of occupational diseases. Poor implementation of preventive & control measure increases the potential risk for workers (Mishra & Malik, 2017).

The condition of health and safety should be improved to enhance the morale of construction industry and its stakeholders. The terrible condition in the construction industry has occurred for long time. Poor safety condition becomes the hindrance for the development of construction projects in Nepal. These concerns should be addressed to improve the safety and health practices in the Transmission line of Nepal.

The main objective of this research is to identify the prevailing occupational hazards and assessment of risk during the construction of Kaligandaki Transmission Corridor Project. To document the preventive and control measures implemented in Kaligandaki Transmission Corridor Project. To assess the effectiveness of preventive and control measures implemented in Kaligandaki Transmission Corridor Project.

Accidents may cause many human tragedies, de-motivate construction workers, disrupt construction processes, delaying in progress, and adversely effect on cost, productivity, quality and reputation of the projects. As a result, using efficient planning and management approaches to stop them can have a big influence on people's lives as well as the economy (Mishra et al., 2022).

The occupational risks that were present during the construction of the KGTCP will be highlighted by this study. Assessing the severity of those dangers' risks will also be helpful. The preventive and control measures put in place during KGTCP construction will be documented by this study. The efficiency of the preventive and control measures put in place during KGTCP construction will be made clear by this study.

Findings of this study will be benefited to safety engineers, safety officers, safety supervisors and workers involved in the construction of transmission line. Assessment of risks of prevailing hazards will help to set the priorities for application of prevention and control measures to specific hazards. Knowing the effectiveness of preventive and control measures will help to make the degree of improvement.

2 Methodology

The population being studied, the sample process, the research design, the research methodology, and the data collection method. The validity and reliability of the research tool will be discussed.

2.1 Research Design

Research Approach: Both qualitative as well as quantitative research approach was used. Qualitative or observational research approach was used for different data collection modes. Qualitative approach was also used to identify and classify hazards, to assess the types of accidents and assess their risk and to find out the prevention and control measures implemented in KGTCP. Whereas quantitative or experimental research approach was used to perform the analysis of collected data from results of responses of structured questionnaires, from key informant interviews and observation etc. This was a case study research design for transmission line (Fig. 1).

Study Area: Kaligandaki Transmission Corridor Project is starting from Dana, Myagdi to Butwal Nawolparasi in two different sections namely Dana to Kushma section and Kushma to New Butwal Sections (TATA, 2017). The length of Dana Kushma Sections is around 39 km and Kushma to New Butwal Substation is around 87.5 km in length. KGTCP also includes three substations located at Dana, Kushma and New Butwal for the collection and evacuations of electric power generated within the Kaligandaki River Basin from different Hydropower project located into the Kligandaki Basinto the National Grid. KGTCP passes through seven different district Namely Mygdi, Baglung, Parbat, Syangja, Palpa, Rupandehi, Nawolparasi Districts as shown in figure below (Fig. 2).

Study Population and Sample Selection: In this research, the population means all the personnel of Client, Consultant and contractor involved in the construction of Kaligandaki Transmission Corridor Project (Table 1).

Sample Size: The client, consultant and contractor the sample size was taken from each section and substations on the basis of their expertise as a technician and social &environment specialist as 10/4, 7/4, 12/4 respectively. While in case of workers 30 number from each section and substations will be selected randomly for the study purpose (Table 2).

Due to the weather conditions at site most of the site activities at difficult places were closed hence number of participants decreased as targeted in proposal (Table 3).

Method of Data Collection: The primary and secondary data was required to accomplish to this research. Primary data was collected by field visit and interview, questionnaire of the personnel related to the study area. Other and related secondary data was collected from the respective office of the client, the consultant and the

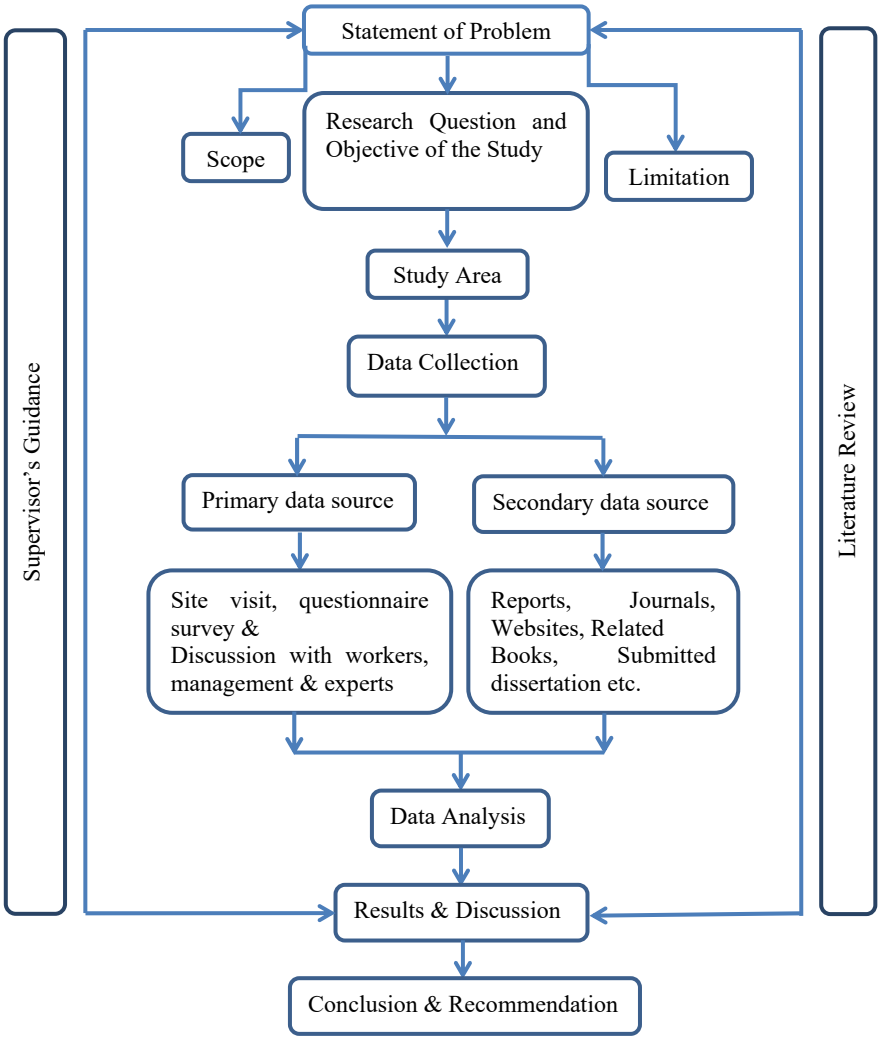

Fig. 1 Research methodology flow diagram

contractor. Inclusive Semi-structured questionnaires were developed for participants from the client, consultant, contractor, experts, workers and local people who are directly or indirectly associated with the project activities (OSHA, 2015b).

Primary Data

Site Observation: To identify the different occupational hazards, uses and effectiveness of preventive measures and control measures, sign and signals, PPE, alarming

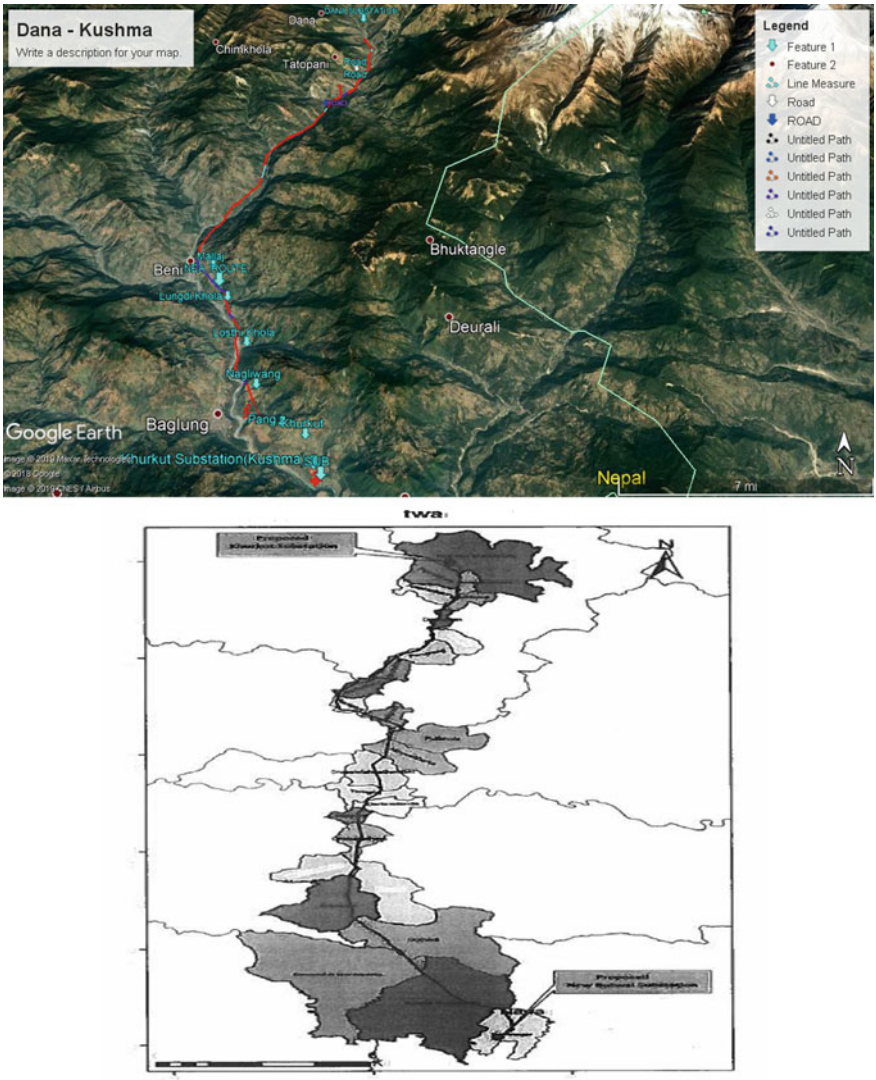

Fig. 2 *Source* Kali Gandaki corridor (Kuhma–New Butwal) 220 kV TL project (IEE Report 2017)

Table 1 Total population size

Total population size (no of personnel from)			
Client	Consultant	Contractor	Workers
30	11	70	300

Table 2 Total sample size and number of responded

Sample size (no of personnel from)						
Client		Consultant		Employers (contractor)		Workers
Engineer/site supervisor	Social and environment	Engineer/Site supervisor	Social and environment	Engineer/Site supervisor	Social and environment	
10	4	7	4	12	4	150

Number of responded				
Project parties	Participant	Targeted	Responded	Rate of respondent (%)
Client/consultant	30	25	10	40
Contractor	40	19	19	100
Workers	250	150	100	67

Table 3 Number of responded

Project parties	Participant	Targeted	Responded	Rate of respondent (%)
Client/consultant	30	25	10	40%
Contractor	40	19	19	100%
Workers	250	150	100	67%

system, medical centers, etc. were collected from the site observation. Also the implementation of the safety procedures and equipment were checked by preparing the check list during site visit.

Key Informant Interview: The Key informant interviews (KII) of the related sector, local peoples, etc. were taken for the validity and reliability of the studies. The KII was based on the snowball sampling. Five experts were chosen for the KII.

Questionnaire Survey: Pretesting was performed to ensure the validity of the questionnaire before it was sent to the respondent's manager, officers, and engineers (employers) for the questionnaire survey (Appendix).

Secondary Data: Secondary data were collected by visiting from the related offices of client, consultant and contractor. Also contract documents, safety plan, related journals, internet were used for collection of secondary data.

Data Analysis: Data analysis was done by using the Microsoft excel which involves data entry, data coding, editing and segregating, and analyzing.

Risk Score: As illustrated in the risk rating matrix, risk score was derived by multiplying consequences (C) and probability (L). The rating of effects (1–5) for various hazards was given based on the responses of respondents to a questionnaire survey, past records of health issues caused by a particular hazard, as well as on judgement and prediction regarding how severely someone might be injured as a result of that particular hazard. Similar to this, the likelihood ratings (1–5) for various hazards were produced based on questionnaire survey responses, historical data on frequency of occurrence, assessment and projection of the likelihood of the consequences, and KII with specialists for a given hazard.

Risk Level Rating: The risk level rating was determined by calculating the risk scores of the various occupational risks that were in use at the time and ranking them in reverse chronological order. According to the OHSAS-18001 foundational principles, risk levels of 20 to 25 are utilised for extreme or critical risk, 12 to 18 for high risk, 6 to 10 for moderate risk, and 1 to 5 for low risk (Table 4).

Research Matrix:

Research objectives	Indicators	Data collection method
To identify workplace risks and evaluate their level of danger	Types of hazards, exposure of hazards, Health Impact, Risk Score etc.	Site monitoring, KII, surveys, and data from the past

(continued)

(continued)

Research objectives	Indicators	Data collection method
To document the preventive and control measures implemented	safety plan, safety Policy, sign and signals used, safety meeting, safety training, PPE, Engineering control, elimination, substitution, administrative control etc.	Questionnaires, Site records, KII
To assess the effectiveness of preventive and control measures implemented	There were no accidents, absences, health effects, etc.	Questionnaire survey, Office records, Observation, KII

3 Results and Discussion

3.1 Occupational Hazards

Main hazards prevailing in transmission line: Table 5 summarized the main hazards prevailed during the construction of Transmission Line. According to the response of respondent 82% of workers responded that the most prevailing hazard during the construction of Transmission line is the Mechanical, 73% of workers responded physical as second most prevailing hazards. Similarly 32% responded Biological, 44% Chemical, 41% psychological and 27% of workers responded ergonomics hazards as the prevailing hazards. Whereas 79% of contractor manager and officer's responded physical hazard is the most prevailing hazard during the construction of transmission line, 63% responded mechanical hazards as the second most prevailing hazard. Similarly 32% responded Biological, 42% responded chemical, 26% Responded Psychological and 21% responded ergonomics hazards as the prevailing hazards (WSU, 2015).

It was observed that construction of transmission line involves major works as a metal works rather than the civil construction works. The workers has to work at height during construction of Transmission towers and equipment's which is so risky work hence the Mechanical hazards can be taken as the most prevailing hazards. But construction works involves civil work as well, towers and other construction works has to be done at hilly reason which creates the equal chance of other hazards too. So it can be said that Mechanical, physical, psychological and biological hazards are the main prevailing hazards on construction of transmission line (Rantanen, 2005).

Common Physical Hazards Prevailing in Transmission line: Table 6 summarizes the occurrence of most common physical hazards. According to the response of responded 55% of workers responded Heat and Humidity as the most common physical hazards occurred at the site, 51% of workers responded Noise as the second highest common physical hazards similarly,31% responded air pollution, 30% responded electric shock, 23% responded cold 2% responded radiation, 1% lighting,

Table 4 Risk assessment matrix (OHSA 18,001)

Level of risk						
Likelihood		Minor	Moderate	Major	Severe	Catastrophic
		1	2	3	4	5
Almost certain	5	5	10	15	20	25
Likely	4	4	8	12	16	20
Possible	3	3	6	9	12	15
Unlikely	2	2	4	6	8	10
Rare	1	1	2	3	4	5
Legend						
20–25	Extreme risk	Needs must be done right now. If at all feasible, stop the action right away				
12–18	High risk	Notify the supervisor and the safety and health representative, take immediate action to reduce injury, and then take the necessary corrective action within two working days				
6–10	Moderate risk	Take the bare minimum of action to prevent harm				
1–5	Low risk	Corrections made within a month				

Table 5 The most common prevailing hazards

Hazards	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Physical	19	15	79	100	73	73
Biological	19	6	32	100	32	32
Mechanical	19	12	63	100	82	82
Chemical	19	8	42	100	44	44
Psychological	19	5	26	100	41	41
Ergonomics	19	4	21	100	27	27

and 4% responded other hazards. Whereas47% of Contractor manager, Engineer and officers responded Air pollution as the main physical hazards, 32% responded both electric and Heat &Humidity as the second most common physical hazards occurred at site. Similarly 5% lighting, 21% others hazards and 0% responded radiation hazards. There is the little bit controversy in between the response of workers and contractor's manager, officers and engineer in responding for the major physical hazards. In researchers observation it was observed that Heat and Humidity, cold and Noise are the main physical hazards prevailing at site (Takele, 2006).

Common source of Mechanical Hazards: Table 7, shows the common source of physical hazards at site. According to table 66% of workers responded that Obstacle

Table 6 The most common physical hazards

Physical hazards	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Noise	19	3	16	100	51	51
Electric shock	19	6	32	100	30	30
Air pollution	19	9	47	100	31	31
Heat and humidity	19	6	32	100	55	55
Radiations	19	0	0	100	2	2
Cold	19	0	0	100	23	23
Lightening	19	1	5	100	1	1
Other	19	0	0%	100	4	4

is the major source of common mechanical hazards present at site, 62% of workers placed Slippery as the second highest source of common mechanical hazards, similarly 58% responded Struck by Machine, 20% responded Slip and Trip, 8% responded Rock Mass Fall, and 6% responded Rock sliding are the source of common mechanical hazards at site. Whereas 53% of contractor Manager, Engineer and Officer responded that defective tools and Equipment's are the major source of common mechanical hazards present at construction site, 37% responded slippery 32% Obstacles, 26% responded Struck by Machine, 31% responded Rock Mass fall and 21% responded Slip and Trip are the source of common mechanical hazards presents at site. It was observed that slippery, defective tools and equipment's, rock mass fall and slip and trip are the most common source of mechanical hazards present at site are shown in Fig. 3.

As per the Table 7, 68% of workers responded that cement dust is the major source of chemical hazards at site, 51% responded sand dust as the second highest source of chemical hazards, similarly 48% responded as an Aggregate dust, 38% responded Metal works, 22% responded welding works, 9% responded chemical spills and 2% responded others were the most common chemical hazards present at site. Whereas 95% of contractors Managers, Engineer and officers responded cement dust as the major source of hazards, similarly 21% responded sand dust, 16% responded paints and galvanizing, 11% responded chemical spills, 5% responded both silica and other hazards were the most common source of chemical hazards present at site. The most common chemical hazards (PMMO, 2007).

It was observed that cement dust, Sand dust and Metal works are the most common source of chemical hazards present at site. It was also found that contractor's safety policy also identified the above hazards may occur at site as shown in Annex 1.

Table 7 The most common sources of chemical hazards

Chemical hazards	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Cement dust	19	18	95	100	68	68
Sand dust	19	4	21	100	51	51
Aggregate dust	19	0	0	100	48	48
Chemical Spills	19	2	11	100	9	9
Metals/paints	19	3	16	100	38	38
Welding	19	0	0	100	22	22
Others	19	1	5	100	2	2

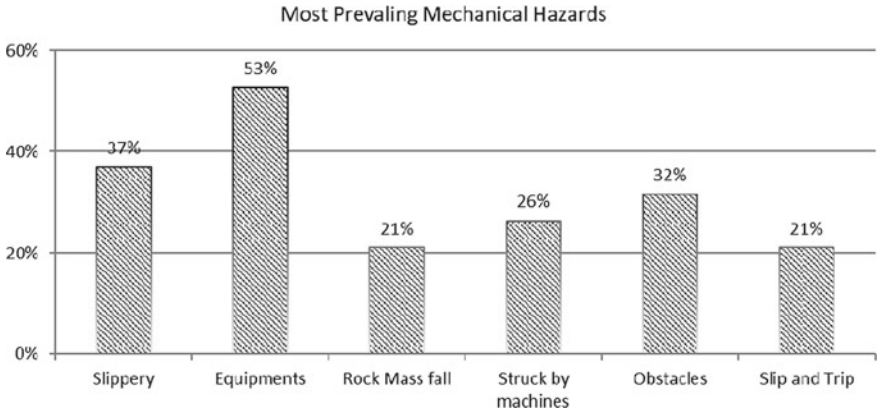

Fig. 3 Most prevailing mechanical hazard

Access to Drinking Water and Toilets

According to the figure, 80% of workers responded that there is an easy availability of drinkable water at site and remaining 20% responded partial availability of drinking water.

After reading the contract document it was found on contract GCC Section 7, clause 22 (d) facilities to workers. During the field visit it was observed that in case of substation and most of the location of towers, availability of water was easy and sufficient for drinking purpose. In some location where workers were facing the scarcity of water were transported through vehicle to fulfill the needs of workers. The major source of water was the natural spring water and ground water used for drinking purpose. Due to use of natural water there was a chance of contamination increasing the opportunity of biological hazards (Alli, 2008). Also it was observed

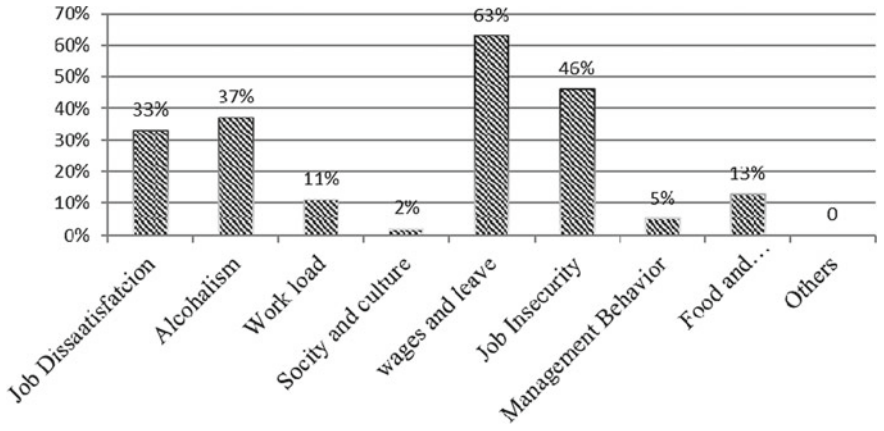

Fig. 4 Major causes of psychosocial hazard

that there was a provision of separate toilets and bath room for male and female in all the substations.

Major Causes of Psychosocial Hazards

It was found that 63% of workers responded wages and leave as the main psychological hazards, 46% of workers responded job insecurity as the second highest psychological hazards similarly 37% responded alcohalism, 32% responded job dissatisfaction, 11% responded work load, 2% responded society and culture, 5% responded management beheavior and 13% responded food and accommodations as the main pshycologcal hazards present at site (Fig. 4).

From the observation it was found that most of the workers were not satisfied with the wages and leave while the Local workes were having the fear of job insecurity. Those workers who came from different places does not have any fear of job inscurity beacsue they are so confident that they will find out the similar type of job in other plasces too. So it was obosrved that, wages and leave, Job insecurity and alchohalism are the main psychological hazards at site. The summary of the psychological hazards are shown on Fig. 4.

Work Related Stress

Figure 5, shows the work related stress faced by workers. Among the workers 42% responded that they had been suffering from the Heat and humidity, similarly 20% responded dead line Pressure, 16% responded cold environment, and 3% responded other are the main work related stress present at site.

It was observed that workers responded as per the terrain conditions where they were involved. Those workers who had been working in the plan area were facing the heat and humidity while workers working in the cold place responded cold as a major work related stress. At the same time it was found that local workers were too

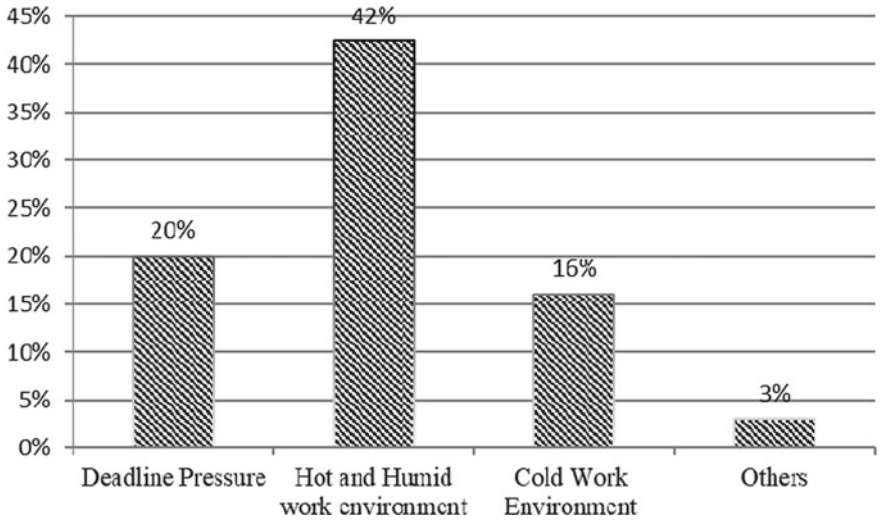

Fig. 5 Work related stress

much familiar with the environment so they placed dead line pressure as the most work related stress faced by them.

3.2 Risk Assessment

Major Health Problems

Summary of the Major health problem shown in Table 8, According to the table, 23 of workers had the problem of back pain, 10% of workers had the problem of wrist pain, 1% had deaf, 1% had faint, 6% had other and 49% of the workers were answered they does not have any kind of health problem. According to Contractors managers, engineers and officers, they have received 32% of complaints regarding the headache as a major health problem, 37% received the complaints about other problems like allergic, stomach problem etc.

It was observed that most of the workers are young as well female workers did not want to share their problem with us. The major health problems were the back pain.

Health Problem Due to Physical Hazards

Figure 6, shows the major health problem of the workers. Among the workers 14% responded that they had been facing the heat related diseases, 5% responded electric shock, 4% responded hearing loss, 4% responded eye strain and 3% had the problem of senseless. Whereas according to the Contractors Manager, Engineer, and officer the most of them faced the problem of Electric shock. 16% responded about the

Table 8 Major health problems

Major health problem	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Deaf	19	1	5	100	1	1
Faint	19	3	16	100	1	1
Headache	19	6	32	100	0	0
Back pain	19	0	0	100	23	23
Wrist pain	19	1	5	100	10	10
Radiations	19	1	5	100	0	0
Sun heat	19	1	5	100	0	0
Other	19	7	37	100	6	6

frequent electric shock, 11% responded about eye strain 5% heat related and 5% hearing loss.

It was observed that the age of workers belongs in between 20 to 40 years so almost all the workers seemed to be healthy also most of the workers were not interested in sharing their problems with us. The Heat related diseases and Electric shock were the main health problem faced by the workers (Josi et al., 2011).

Health Problem Due to Chemical Hazards

According to the Contractors Manager, Engineer, and officers 74% of workers complained about the Allergic problem, 11% complained about the corrosive, 11% complained chronic bronchitis, and 5% complained about carcinogenic. Whereas almost all the workers responded they don't have any kind of such health problem.

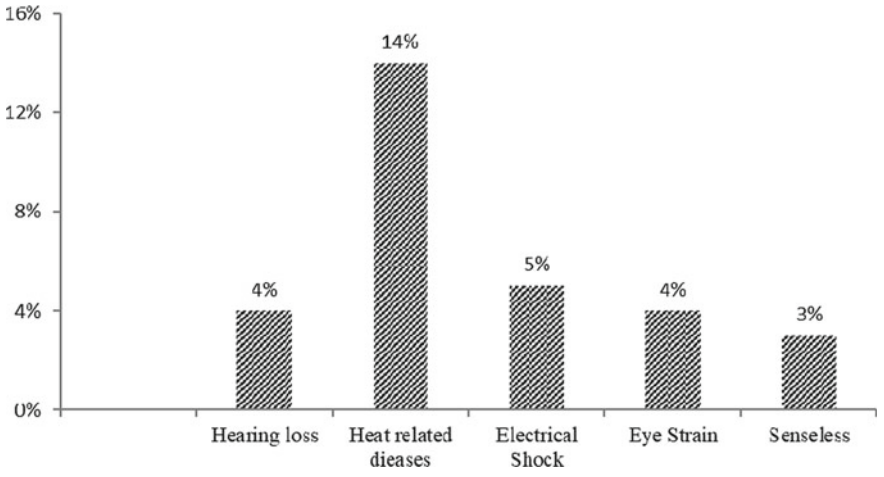

Fig. 6 Health problems due to physical hazards

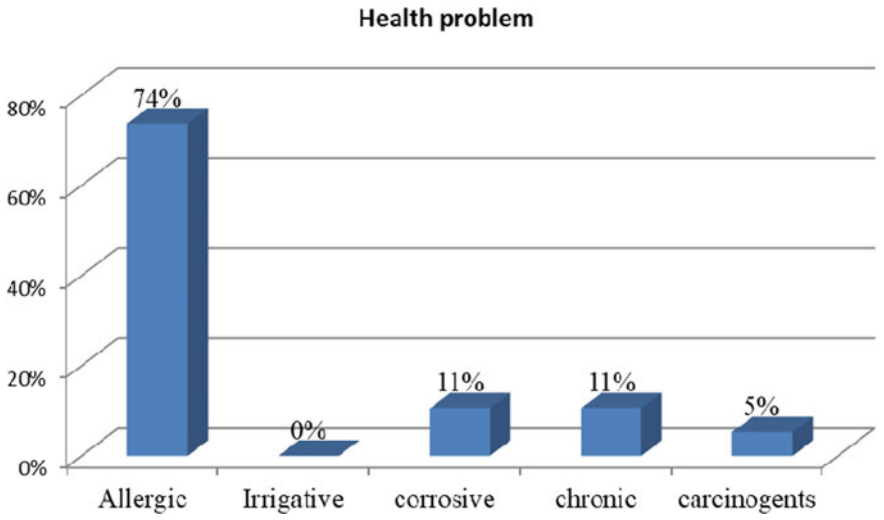

Fig. 7 Health problem due to chemical hazards

It was observed that workers do not want to share their health problems with us. Figure 7, shows the response of towards health problem due to chemical hazards (Pingle, 2012).

Health Problem Due to Bad Ergonomics

Experts' key informant interviews revealed that wrist discomfort and headaches were the two health issues that workers experienced as a result of poor ergonomics.

Risk of Rock Fall in Transmission Line

According to the observation and KII expert, most of the tower locations are located in hilly areas so there is always a big chance of rock fall from top of the hill. Also there had been always a great chance of rock fall during the excavation of foundation of towers.

Risk of Falling from Tower and Conductor

From the observation and KII expert experience, during erecting and stringing of towers and conductor the materials and tower parts has to be lifted and transported from difficult terrain which increases the chance of falling of both materials and workers. Also due to the poor condition of tools and equipment's used during tightening of nuts and bolts there is chance of falling of tower parts. So there has been always a risk of falling from tower and conductor during construction of transmission line.

Table 9 Provision of medical examination

Provision of medical examination	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no of responded	Frequency	Response (%)
Monthly	19	5	26	100	8	8
In every six month	19	12	63	100	0	0
Yearly	19	1	5	100	14	14
Once in project	19	0	0	100	5	5
Never	19	0	0	100	73	73

Medical Examinations

Table 9 shows that the provision of medical examination at site. According to table 73% of workers responded there was no any provision of medical examination on the site, 14% workers responded there was a provision of medical examination facilities once in a year, 8% of workers responded there was the provision of medical examination facilities monthly and 0% workers responded provision of medical facilities half yearly. Whereas 63% of contractors Manger, Engineer, and officer, claimed that they are providing medical facilities in every six months, 26% claimed that they are providing the medical examination in every months, 5% claimed that medical facilities are providing in yearly basis.

After reading the contract document SCC clause 22.2.7(d) covered somehow the provision of medical examination which includes "conduct Information, All site staff and labour (including all Contractor, Sub-Contractor, Employer, and Project Manager employees, as well as all truck drivers and crew making deliveries to the site for construction activities) as well as the nearby local communities will receive education and consultation communication (IEC) campaigns at least every other month about the risks, dangers, and impact of sexually Transgender people. During observations and according to KII informant it came to know that contractor had carried out the medical examination once in project.

Risk Rating Matrix

See Table 10.

Table 11 shows the risk rating matrix on reverse chronological order. Risk was calculated by multiplying the likelihood and consequences. After calculating; the risks are rated on the basis of OHSA's risk rating matrix. According to the OHSA risk rating matrix, risk is divided into the four different categories extreme, high, moderate and low. Depending upon the categories it is finalized that which actions have to take for preventing, minimizing and controlling the possible accidents at site (OSHA 3302–99). For calculating the risk; likelihood and consequences were rated on the basis of experience of KII experts.

Table 10 Risk rating matrix

	Risk score = Likelihood (L) × Consequences (C)				
Types of hazards	Occupational hazards	Likelihood (1–5)	Consequences (1–5)	Risk score	Risk level rating
Mechanical	Slippery	4	3	12	High
	Rock sliding	3	3	9	moderate
	Rock mass	2	4.2	8.4	Moderate
	Struck by machine	3	3.5	10.5	Moderate
	Slip and trip	3	3	9	Moderate
	Obstacles	5	2.5	12.5	High
Fall hazards	Fall from towers and conductors	4	5	20	Extreme
	Fall from scaffolding	3.5	4.5	15.75	High
	Fall from ladder	2	2.5	5	Low
	Fall from roof	1	5	5	Low
Physical	Noise	3	1.5	4.5	Low
	Electric shock	3	2.5	7.5	Moderate
	Air pollution	4	1.5	6	Moderate
	Heat and humid environment	3.5	2.5	8.75	Moderate
	Radiations	1	4.5	4.5	Low
	Cold environment	2.5	2.5	6.25	Moderate
	Lightening	1	5	5	Low
Exposure hazards	Hitting by falling object	2	3.5	7	Moderate
	Unprotected edges	3	4.5	13.5	High
	Chemicals	2	2.5	5	Low
	Tools & equipment	4	3.5	14	Moderate
	Snake bites	2	5	10	Moderate
Chemical	Dust (cement dust, Sand dust, aggregate dust etc.)	5	2	10	Moderate
	Metals/paints	4	1	4	Low
	Welding	2	2.5	5	Low

(continued)

Table 10 (continued)

	Risk score = Likelihood (L) × Consequences (C)				
Types of hazards	Occupational hazards	Likelihood (1–5)	Consequences (1–5)	Risk score	Risk level rating
Psychological hazards	Job dissatisfaction	4.5	1.5	6.75	Moderate
	Alcoholism	2	2	4	Low
	Work load	4	3	12	High
	Society culture	1	2	2	Low
	Wages and leave	4	1.5	6	Moderate
	Job security	4	1.5	6	Moderate
	Management behavior	4	1	4	Low
Work related stress	Dead line pressure	4	2.5	10	Moderate

From the risk rating matrix, fall from towers and conductors seems to be the most risky activities during erecting and stringing of transmission line. This means that before starting the erection and stringing work safety officers managers, engineers and supervisor must have to be confident regarding the availability of sufficient safety equipment's and has to check its proper use. If found any defect during construction immediate actions has to take for remedial measures.

From the table it seems that, fall from scaffoldings, tools and equipment's, unprotected edge, obstacles, work load and slippery falls into the category of high risk work. So during the execution of these activities it has to notify to safety officers or site engineers to take the immediate action to minimize the injury and possible accidents. If found defect remedial measures has to be completed within the two working days (BLS, 2014).

From the table it seems that, struck by machine, snake bites, deadline pressure, dusts, slip and trip, rock sliding, heat and humid environment, rock mass fall, electric shock, hitting by falling object, job dissatisfaction, cold environment, air pollution and wages and leave falls into the category of moderately risky activities. To minimize the possible accidents for these activities safety officers, managers and engineers has to take the immediate actions towards fixing the sign and signals, toolbox talks, safety briefing etc. while carrying out these operations if found defective remedial measures can be made within five working days.

From the table it seems that, job security, welding, chemicals, lightning, fall from ladder, fall from roof, noise, radiations, metal paints, alcoholism, management behavior and society and culture falls into the low risk activities which needs the remedial measures within one month.

Accident and Major Causes

Table 11 Risk rating matrix in reverse chronological order

	Risk score = Likelihood (L) × Consequences (C)				
S. No	Occupational hazards	Likelihood (1–5)	Consequences (1–5)	Risk score	Risk level rating
1	Fall from towers and conductors	4	5	20	Extreme
2	Fall from scaffolding	3.5	4.5	15.75	High
3	Tools & equipment	4	3.5	14	High
4	Unprotected edges	3	4.5	13.5	High
5	Obstacles	5	2.5	12.5	High
6	Work load	4	3	12	High
7	Slippery	4	3	12	High
8	Struck by machine	3	3.5	10.5	Moderate
9	Snake bites	2	5	10	Moderate
10	Dead line pressure	4	2.5	10	Moderate
11	Dust (cement dust, Sand dust, aggregate dust)	5	2	10	Moderate
12	Slip and trip	3	3	9	Moderate
13	Rock sliding	3	3	9	Moderate
14	Heat and humid environment	3.5	2.5	8.75	Moderate
15	Rock mass	2	4.2	8.4	Moderate
16	Electric shock	3	2.5	7.5	Moderate
17	Hitting by falling object	2	3.5	7	Moderate
18	Job dissatisfaction	4.5	1.5	6.75	Moderate
19	Cold environment	2.5	2.5	6.25	Moderate
20	Air pollution	4	1.5	6	Moderate
21	Wages and leave	4	1.5	6	Moderate
22	Job security	4	1.5	6	Moderate
23	Welding	2	2.5	5	Low
24	Chemicals	2	2.5	5	Low
25	Lightening	1	5	5	Low

(continued)

Table 11 (continued)

	Risk score = Likelihood (L) × Consequences (C)				
S. No	Occupational hazards	Likelihood (1–5)	Consequences (1–5)	Risk score	Risk level rating
26	Fall from ladder	2	2.5	5	Low
27	Fall from roof	1	5	5	Low
28	Noise	3	1.5	4.5	Low
29	Radiations	1	4.5	4.5	Low
30	Metals/paints	4	1	4	Low
31	Alcoholism	2	2	4	Low
32	Management behavior	4	1	4	Low
33	Society culture	1	2	2	Low

Provision of compensation against accident in contract document

The response from every member of the client/consultant team was that the contract has a provision for accident compensation. The Key Informant interview with the contractor's management revealed that the contract included a provision for accident compensation.

Accident occurred in construction of Kaligandaki Transmission corridor Project

57% of workers responded about occurrence of minor accidents and 100% contractor's managers, engineer, officers and clients responded that there is no any accident occurred at site till now. All the involving employees claimed that only the minor accidents were occurred at site during the construction of KGTCP. But according to KII informant and local people one worker died by falling from cliff due to alcohol and another worker found dead in bed without any reason.

Accident and Their Degree of Injury

100% of all the contractor, clients and consultant responded that there was only the minor injury held on the site. According to the KII informant and local people only one or two small hand cut injury were noticed and sent them to hospital for the treatment. So there have not been any major injury occurred at site during the construction of KGTCP.

Types of Accidents Occurred at Site

Table 12 shows the result of accident occurred at site. 100% of workers responded that minor injury occurred at site. Also 100% of contractor manager, engineer, and officer responded there was only the minor injury held at the site.

It is mentioned in the contract document that "Details of any mishap must be sent by the Contractor to the Project Manager as soon as practically possible after it

Table 12 Type of accident occurred at site

Types of accidents	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	% of response	Total no. of responded	Frequency	% of response
Minor	19	19	100%	100	100	100%
Major	19	0	0%	100	0	0%
Fatal	19	0	0%	100	0	0%

occurs. The Contractor must keep records and provide reports about people's health, safety, and welfare as well as any property damage as the Project Manager may reasonably request".

After the observation it was found that after concerning with clients engineers contractor never noticed about any accidents held on site. But according to the KII informant, client Engineer and Local people, one worker died by falling from vertical cliff due to over drunk and another worker found dead in the morning in his bed without any injury (Fingrid's, 2018).

Most Risky Activities at Site

Table 13 shows the list of most risky activities during construction of transmission line. According to the table 77% of workers responded Erection and Stringing were the most risky activities, 14% responded deep excavation, 13% responded scaffolding and 2% responded lifting and transportation as the main risky activities in construction of transmission line. Whereas 100% contractor's Manager, Engineers and Officers responded erection and stringing as the most risky activities during construction.

Table 13 Most risky activities at site

Risky activities	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Erecting and stringing	19	19	100	100	77	77
Deep excavation	19	1	5	100	14	14
Concreting work	19	0	0	100	0	0
Lifting and Transportation	19	0	0	100	2	2
Scaffolding	19	0	0	100	13	13
Others	19	1	5	100	1	1

In researchers observation the most risky activities was the erection and stringing because workers had to work at height and even a small mistake might lead to a serious injury leading towards permanent disability or death. KII expert also agrees with the results. Major risky activities are erection and stringing, excavation, and scaffolding.

But a similar research conducted on Occupational Geological Mapping and scaling as the most risky activities as during construction of Tunnel (Mishra et al., 2019).

Responsible Parties for Accident

Figure 8, shows the result of responsible parties for accident at site. According to table 65% of workers responded that workers themselves are responsible for accident, 36% responded contractors are the main responsible parties for accidents, while 4% responded client is the responsible parties for accidents but 0% responded that government is the responsible parties. Also 74% of contractor's Manager, Engineer and officers responded workers are the main responsible parties for accidents, 58% accepted contractor as a responsible parties, and 26% responded clients, 21% responded consultant and 11% respondent government must be the responsible parties (ILO, 2015).

In researcher's observation contractor, client and consultant must be responsible for accidents.

According to KII experts all parties like Workers, Contractor, Client, Consultant and Government should be responsible for the accident at site. During conceptualization and planning client must have to consider for safety, during designing consultant must be responsible; during implementation contractor must be responsible for the safety and at last Government is responsible for checking the effective implementation of safety laws and regulations available in Nepal (PPDK, 2015).

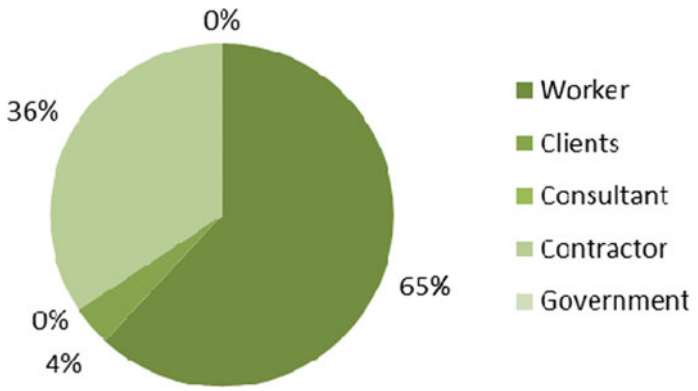

Fig. 8 Responsible parties for accident at site

Accidents due to Exposure of Hazards

Table 14 shows the results of Accident due to exposure of different hazards prevailed in transmission line. 44% workers responded tools and equipment is the main cause of accidents due to exposure, 40% responded fall from height, 31% responded hitting by falling object, 24% responded struck during transportation, 5% responded chemical, 1% responded unprotected edge and 9% responded others are the accidents caused due to exposure. Whereas 26% of contractor's Manager, Engineer, Officers responded that unprotected edge is the main cause of accidents due to exposure, 16% responded falls from height, 21% responded defective tools and equipment's causing the accidents due to exposure.

As per researcher observation unprotected edge, radiations and fall from height are the main cause of accidents due to exposure. Due to poor housekeeping most of scrap materials were spread haphazardly causing the accidents. Also due to lack of provision of proper protective barricades and carelessness of the workers there is always been a chance of accident due to exposure (FIDIC MDB, 2010).

A similar research conducted on Occupational hazard and also found fall hazard as the most common cause of accidents due to exposure (Lama et al., 2019).

Major Causes of Accidents at Site

Figure 9, shows results of major causes of accidents at site. 63% of contractor's Manager, officers and Engineer responded lack of skill is the main cause of accidents,

Table 14 Accident due to exposure of hazards

Hazards due to exposure	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Fall from height	19	3	16	100	40	40
Electricity shock	19	0	0	100	23	23
Hitting by falling object	19	1	5	100	31	31
Unprotected edges	19	5	26	100	1	1
Chemicals	19	1	5	100	5	5
Tools & equipment	19	4	21	100	44	44
Radiations	19	1	5	100	0	0
Snake bites	19	2	11	100	0	0
Struck during transportation	19	0	0	100	24	24
Others if any	19	1	5%	100	9	9%

58% responded main cause as carelessness of workers and put it into second place, 53% responded lack of training and orientation, while 42% responded lack illiteracy and inexperience are the cause of accidents. Whereas 46% of workers responded the major cause of accidents is the illiteracy and inexperience, and 45% responded lack of skill and knowledge is the cause of accidents, 33% responded that the cause of accidents is training and orientation. It had been observed that there is no any major accident occurred at site till date and most of the cases are first aid case only.

It was also observed that the main cause of first aid cases are due to careless ness of the workers as well as due to improper use of PPE provided by the contractor. While handling the metals at site it was found that workers did not wear the gloves even though they had which are causing minor hand cuts and snatching of skins.

A similar research conducted on Occupational hazard identification and risk assessment found the major cause of the accidents at construction of HRT as the lack of skill & knowledge (Lama et al., 2019).

Most Common Causes of Fall Accident

As shown in Fig. 10 shows the response towards most common fall accidents at site. According to response of workers it was found that 52% of workers responded the most common fall accidents occurred at site is the fall from tower and conductor, 50% responded as the second highest causes of fall accidents is the fall from scaffolding. It was observed that the most common causes of fall accidents is fall from towers and conductors during the erection and stringing of tower and conductors (Lamont, 2015).

Also it was observed that those workers who are involved in civil construction works responded scaffolding is the main cause of fall accidents whereas who are involved on metal works they responded fall from tower is the main cause of fall

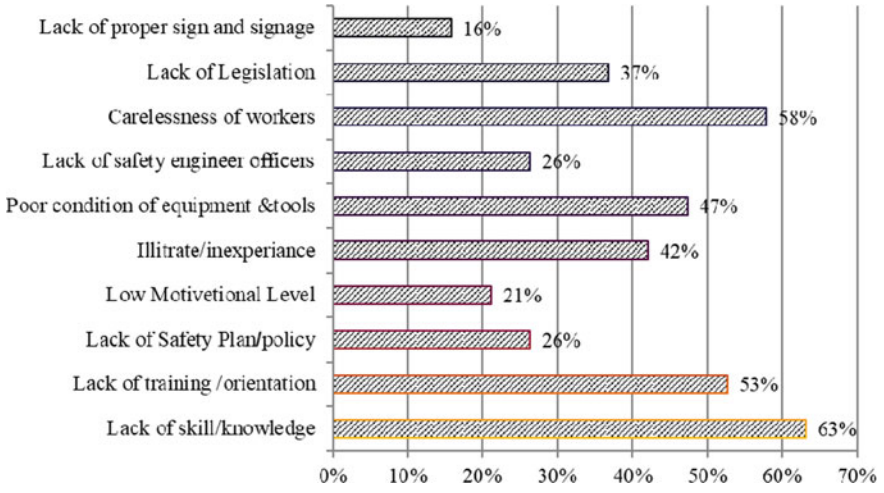

Fig. 9 Causes of accidents at site

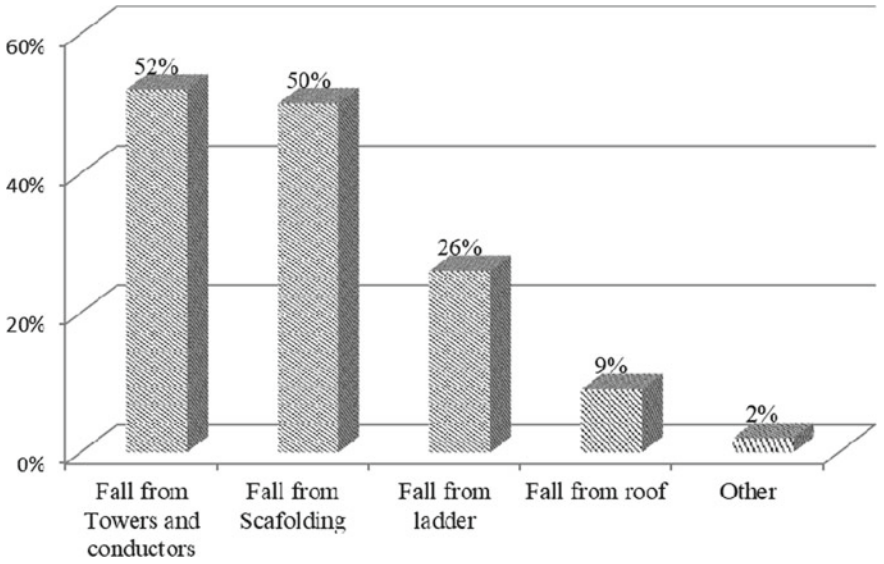

Fig. 10 Most common cause of fall accident

accidents. According to the KII expert the main cause of accidents are the fall from tower and conductors for fitters and scaffolding for civil workers These hazards were also included on literature review. The environment plan of TATA projects Ltd. Also determines the above stated cause (TATA, 2017).

3.3 Preventive and Control Measures Implemented

Knowledge of safety and health provision in Nepalese Act

The result of Knowledge of safety and health provision in Nepalese act as well as International laws. About 33% of workers responded that they know about the provision of safety about Nepalese and international acts (ILO, 1919, 1996, 2003).

Preventive measures used to prevent accident

Figure 11 shows the results of Preventive measures used to prevent accidents at site. According to the table 86% of workers responded that sign and signals are provided to prevent the accidents, 51% of workers responded good housekeeping are being maintained to minimize the accidents, 43% of workers responded orientation and awareness program are carried out to prevent accidents. Whereas 84% of contractor's Manager, Engineer and officers responded that they have provided good training to the workers to prevent accidents at site, 74% responded orientation and awareness have been provided to prevent the accidents at site, 58% of contractor manager,

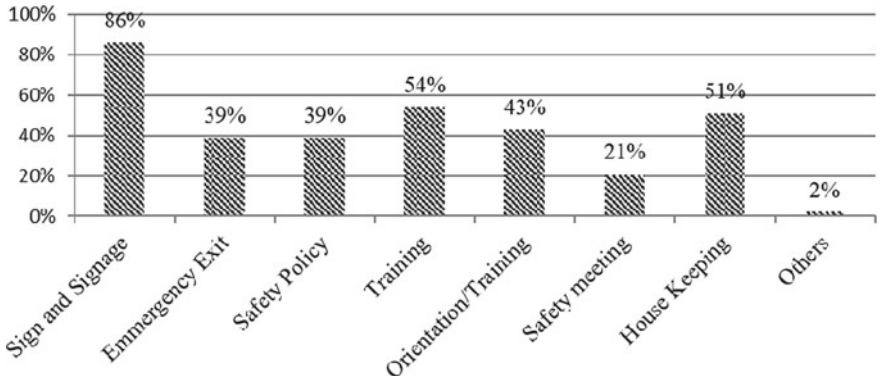

Fig. 11 Preventive measures used to prevent accidents at site

engineer and officers claimed that they have provided sign and signal and good housekeeping to prevent the accidents at site (CBS, 2009).

From the above result there are some conflicts in between the response of workers and contractor mangers but it was observed that during the site visit there is the good provision of sign and signal along with safety briefing and tool box talks. Sign and signals are provided at almost all the places properly, contractor has constructed a safety park to demonstrate about the proper use of PPE's and barricades are being provided to protect unauthorized entry in to the deep excavation. Contractor has tried to maintain the good housekeeping by storing the scrap materials in separate compartment based on their category. It was found that in case of substation safety officer providing toolbox talks training and safety briefing before starting the work. So according to the observation housekeeping, training, safety orientation and awareness are the major measures carried out to prevent the accidents at site (Kairala, 2018).

Control Measures Used to Control Accident

Figure 12 shows the result of control measures carried out at site. 95% of contractor's Mangers, Engineer and Officers responded that they have provided the PPE's, 47% responded about Elimination, 42% responded Engineering, 37% administrative, 32% responded substitution measures are being carried out to control the possible accidents. In researchers observation almost all the workers have been using the PPE's and somehow engineering measures are being used in some extent but implementations of other control measures are in poor condition.

Availability of Safety Engineer/Officer

As shown in table, 98% of workers responded that safety officers and engineers are available at site, 100% of contractor's Manager, Engineer and officers responded the availability of safety officer at site. Also 100% of employers and consultant were agreed with the contractor and workers response (Table 15).

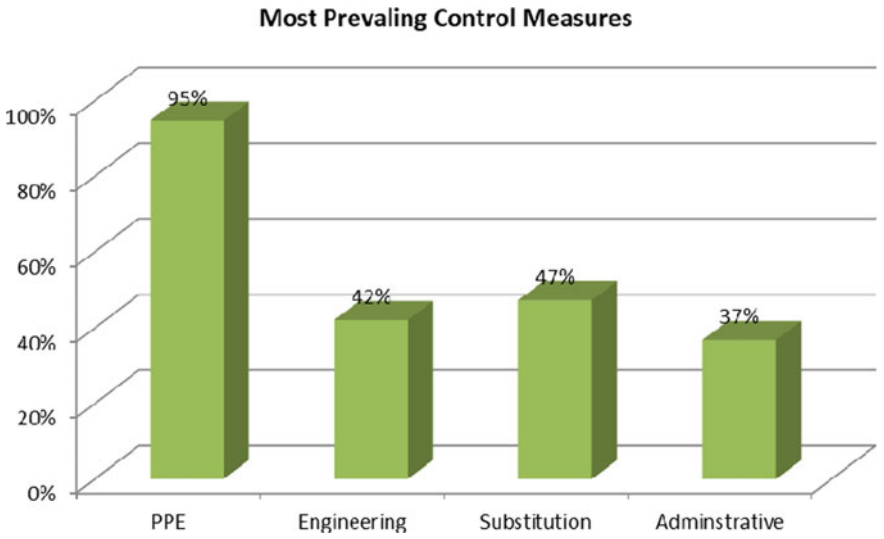

Fig. 12 Control measures used to control accidents

Table 15 Types of safety training conduction

Provision of safety officer at site	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Yes	19	19	100	100	98	98
No	19	0	0	100	2	2

The contract documents provide that the contractor must designate a site accident prevention officer who will be in charge of upholding security and accident prevention. The person in charge of this duty must possess the necessary training and power to provide orders and implement safety precautions. In researchers observation it was observed that contractor has deputed a sufficient number of safety officer's at site as per the requirements of contract (HSE, 1974, 2014, 2015).

Types of Safety Training Conduction

Table 16 summarizes the result of types of safety training conduction at construction site. 95% of workers responded that tool box talks training had been provided to them, 41% of workers responded safety briefings are given to them. Whereas 74% of Contractor's Manager, Engineer and officers responded that they have provided induction training, 63% responded safety briefing, each 58% responded toolbox training and skill development training and 21% responded that they have provided shop training. The results seem to have conflicts in response between the workers and contractors representative (Heaven, 2012).

Table 16 Types of safety training conduction

Types of training conducted	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Induction	19	14	74	100	23	23
Toolbox training	19	11	58	100	95	95
Safety briefing	19	12	63	100	41	41
Skill development	19	11	58	100	10	10
Shop training	19	4	21	100	0	0

According to the KII informant toolbox training have been provided to the workers and also during the entry of new workers contractor had provided the induction training to make familiar with the work which they are going to do. In researchers observation toolbox training is the major training provided by the contractor.

Safety Meeting

98% of workers responded that they attend any safety meeting at site. From KII informant it came to know that safety officer arrange the safety meeting every day as and when required.

Safety Inspection

Table 17 summarizes the result of current status of attending safety inspection at construction site. About 73% of workers responded that inspection are carried out on daily basis, 15% responded twice in week, 7% responded once in week and 5% responded once in a months. Exactly 100% of Contractor's Manager, Engineer and Officer responded that safety inspection is carried out on daily basis.

According to KII informant and my observation safety inspection being carried out every day in all the substations and twice in a week in transmission line towers. The EHS plan of TATA Projects Ltd. Included the organization chart of safety department.

Safety Audit

Figure 13 summarizes the results of safety audit at site. Exactly 50% of clients responded safety auditing is being carried out on yearly basis and 40% of clients and consultant responded there is no provision of safety audit on project.

It was observed that contractor has carried out the safety audit monthly and submitted it to client as well as to his own safety department.

Reporting of Safety System Mentioned in Contract Document

Figure 14 shows the results of reporting system mentioned in contract document. 60% of clients and consultant responded that there is safety reporting system included in

Table 17 Safety inspection at site

Safety inspections agency		Contractor's manager, engineer, officer			Workers		
		Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Safety officer/engineer	Daily	19	19	100	100	73	73
	Twice a week	19	0	0	100	15	15
	Once a week	19	0	0	100	7	7
	Once a month	19	0	0	100	5	5
Third party Inspection	Yes	19	16	84	100		
	No	19	3	16	100		
Inspection by Government	Yes	19	17	89	100		
	No	19	2	11	100		

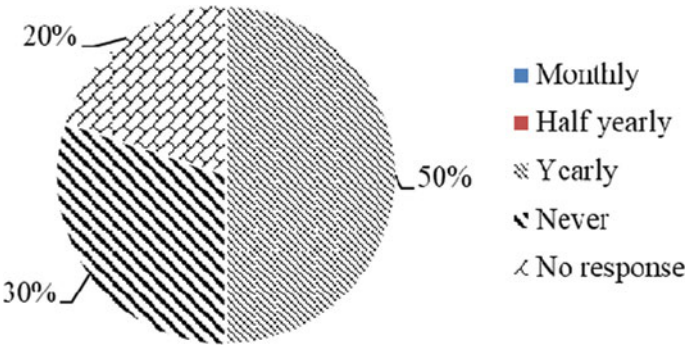

Fig. 13 Safety audit at site

monthly basis, 20% client and consultant responded yearly basis, 10% responded weekly basis 0% responded there is no any reporting system included in contract document.

Documented Safety Policy, Plan and Procedure

Figure 13 demonstrate the result of documented safety policy, plan and procedures. Employers said that their safety policies, plans, and procedures were all documented in about 100% of cases. According to the researcher's findings, the contractor gave the client the safety plan and process.

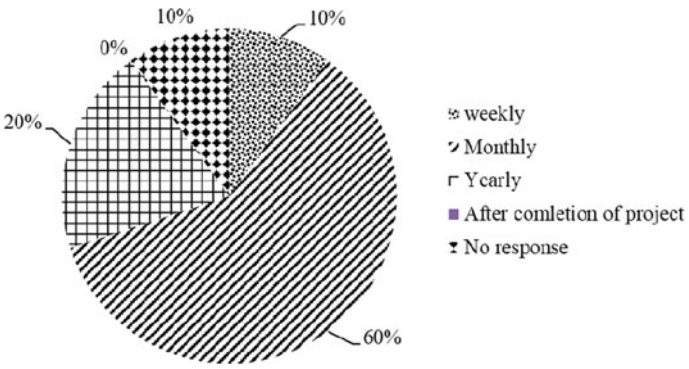

Fig. 14 Reporting of safety system mentioned in contract document

Practice of Safety Sign, Signal and Notice

Table 18 shows the result of practice of safety, sign, signal and notice at site. 96% of workers responded that there is a provision practice of safety Sign, Signal and Notice on site. Equally 96% of contractors Mangers, Engineer and officers responded about the provision of safety sign, signal and notice board at site.

In researchers observation there is a good provision of sign, signal and notice at site.

Emergency Exit and Assembly Point

According to the contract document "If, by reason of an emergency arising in connection with and during the execution of the Contract, any protective or remedial work is necessary as a matter of urgency to prevent damage to the Facilities, the Contractor shall immediately carry out such work". Figure 15 summarizes the result of current Provision of Emergency exit, assembly point and alarming system in case of emergency at construction. 28% of workers responded regarding the provision of emergency exit and alarming system and 100% of contractor's Manager, Engineer and officers responded about the provision of emergency exit during the accidents.

Table 18 Practice of safety sign, signal and notice

Practice of sign and signals, notice board	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Yes				100	96	96
No				100	2	2
Always	19	16	84			
Partially	19	3	16			
Never	19	0	0			

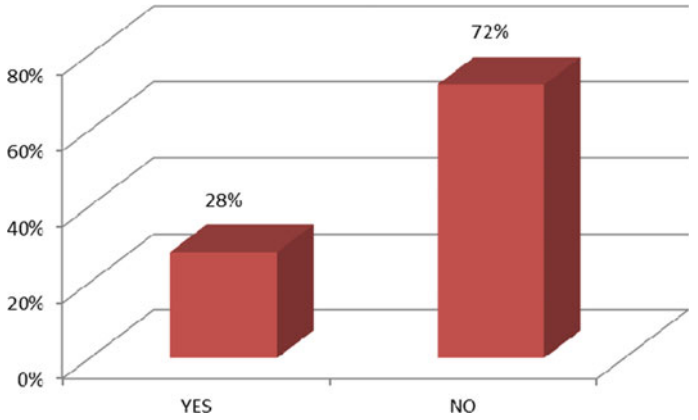

Fig. 15 Provision of emergency exit and alarming system

In researchers observation all the works are being carried out on open places so there may not be required to provide the emergency exit however it was found that there is no any provision of alarming system in the site.

Status of Obeying Safety Instruction, Laws, Rules and Regulation

Table 19 shows the status of obeying the safety instruction, Rules and Regulation on project. 63% of Contractor's Manager, Engineers and Officers responded that all the employees follow the instruction, laws, rules and regulations as mentions in Nepal, 32% responded they will follow the instruction, laws, rules and regulations sometimes partially.

In contract document it was written that "The Contractor is required to give its employees access to all of their legal rights under all applicable labour laws, including those pertaining to their employment, health, safety, welfare, immigration, and emigration". Also in clause 22.4 it is included regarding the site regulations according to which "In order to carry out the contract at the site, the Employer and Contractor must develop Site Regulations, and both parties must abide by them. Proposed Site regulations must be created by the Contractor and submitted to the Employer with a copy to the Project Manager for approval, which cannot be unreasonably withheld. These site rules must address issues like security, facility safety,

Table 19 Status of obeying safety laws, rules and instruction by workers at site

Obeying of safety rules, laws and regulations	Contractor's manager, engineer, officer		
	Total no. of responded	Frequency	Response (%)
Always	19	12	63
Partially	19	6	32
Never	19	0	0

gate control, hygiene, medical attention, and fire prevention, among other things" (Mishra, 2018).

In researchers observations it was found that contractor tried his best to comply the requirement as per the contractual provision.

Safety Budget

Table 20 shows the result of allocation of Safety budget at construction site.80% of client and consultant responded that safety budget has been allocated, whereas 98% of contractor's manager, engineers and officers responded that safety budget is allocated for the project.

After reading the contract document there is no any separate provision of safety budget but BOQ schedule, 2 supply and installations parts of contract documents, includes supply of PPE items by contractors (Gautam & Praskhain, 2011).

In researchers observations and KII informant Contractor has the budget towards safety which is unlimited depending up on the case of accidents at site.

Use and Availability of Sufficient PPE

Elimination, Engineering, substitution administrative control, are the measures used to prevent and minimize the accidents by using the knowledge and management skills it does not involved in construction activities directly. In construction work these kinds of safety measures may not be effective and sufficient to protect the health and safety of the workers who are directly in contact with the possible hazards in such cases there is only the remaining options to protect health and safety of the workers are PPE's. So PPE's are taken as the last line of defense for protection of health and safety of the workers (Sunil, 2011).

100% of workers responded that there is a good provision of PPE at site. 97% of workers responded that PPE are sufficient for them. Also 100% of contractor manager, engineer and officers responded that PPE are provided to the workers. During the site visit it has been observed that almost all of the workers worn the PPE. But most of the workers were found not using the PPE properly; it was found safety shoes were not worn by most of the workers because of heat and humidity at site (Table 21).

This checklist was prepared during the site visit.

Table 20 Allocation of safety budget

Allocation of safety budget	Client/consultant			Contractor's manager, engineer, officer		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Yes	10	8	80	19	18	95
No	10	2	20	19	1	5

Table 21 Safety check list of PPE

A	Personal protective equipment: needed at this worksite?	Yes	No	PF	Don't know	Comments
1	Hard hats					
	Supplied by contractors	Yes				
	Worn properly when required	Yes				
2	Boots/safety shoes					
	Supplied by contractors	Yes				
	Worn properly when required			PF		Provided but not used properly
3	Hearing protection					
	Supplied by contractors		No			
	Worn properly when required		No			
4	Eye protections					
	Supplied by contractors			PF		
	Worn properly when required					Used when required
5	Respiratory Protection					
	Supplied by contractors	No				
	Training provided	No				
	Worn properly when required					
6	Hand protection					
	Supplied by contractors	Yes				
	Worn properly when required			PF		Provided but not used properly
7	Safety Belt					
	Supplied by contractors	Yes				
	Worn properly when required	Yes				

Table 22 First aid provision

Provision of first aid	Contractor's manager, engineer, officer			Workers		
	Total no. of responded	Frequency	Response (%)	Total no. of responded	Frequency	Response (%)
Yes	19	19	100	100	96	96
No	19	0	0	100	4	4

Provision of First Aid Facilities

Table 22 shows the provision of first aid facilities at site. 100% of Contractor's Manager, Engineer and officers responded that there is the provision of first aid facilities at site. 96% of workers responded that availability of first aid facilities at site.

After reading the contract document it was found on General condition of contract, section, 7 clauses 22. "The Contractor is required to always take every care necessary to protect the health and safety of the Contractor's Personnel. In coordination with local health authorities, the contractor is responsible for making sure that there is always access to medical personnel, first aid supplies, a sick bay, and an ambulance service at the site and at any accommodations for the contractor's and employer's personnel, as well as for making the necessary preparations for all welfare and hygienic needs as well as for the prevention of epidemics."

But it was observed that, there is no any provision of ambulance, no any medical staff was appointed only the first aid box are provided at site.

Establishment of Medical Clinic

It was observed that medical clinic is established in one of the substation only in other places like in transmission line there is no any provision of medical clinic. According to KII informant contractor did an agreement with the local hospitals to carry out the treatment in case of emergency.

Provision of Medical Examination

According to the contract document GCC section 7, clause 22.2.7 "The Contractor is responsible for implementing health and safety programmes for project employees. These programmes must contain information on the risk of sex trafficking and sexually transmitted illnesses, such as HIV/AIDS". But 73% of workers responded that they never attended any medical examination in the project, 14% responded that they attend the medical examination every year. While 63% of contractor's Manager, officer and engineer claimed that they have been provided the medical examination every months. In researchers Observation and according to the KII informant it came to know that contractor has carried out a medical examination once in a project (DOL, 2009).

Compensation and Insurance Policy

56% of workers responded that they know about the compensation and insurance policy available in the project. 100% of employers, clients and contractor manager, engineer and officers responded that there is the provision of compensation and insurance at site.

After reading the contract document it was found that there is the provision of insurance for various items but for workers it is written that "Workers Compensation is in accordance with the statutory requirements applicable in any country where the Contract or any part thereof is executed". It was observed that most of the workers were unknown about the contractors all risk insurance but as per the contract document CAR has done by the contractor which includes insurance of workers as well. So it may say that there is the provision of compensation and insurance policy at this project.

Absenteeism due to health problem and

Table 23 below shows the rate of absenteeism per worker per months of 31 workers working at New Butwal substations of KGTCP for the months of Jesth, Ashad, Shrawon 2076. (Attendance of workers of New Butwal Substation) are shown in Appendix V.

It was observed that the average absenteeism of the women was little bit higher than the men. The Average absenteeism of men is 5.6 days/workers/months and for women 6.63 days/worker/months.

Effectiveness of Preventive and control measures used

According to the KII expert effectiveness of preventive and control measures indicates the rate of accidents at site, rate of absenteeism and health problem faced by workers due to occupational health and safety. As per the response of client, consultant and contractors officers, about 100% responded that the preventive and control measures adopted are very effective. The list of operational control procedure prepared by TATA projects Ltd. Is shown in Annex I.

In researchers observation contractor has prepared and submitted the safety plan to prevent and control the possible accidents. The control measures adopted by the contractors are as follows, and found to be effective till 10-9-2019.

Degree of Challenge to Implement Safety Measures at Site

Figure 16 shows the result for Degree of challenge to implement safety measures at site.

80% of clients and consultant responded that it is difficult to implement the safety measure at site while 20% responded that it is very difficult to implement the safety measures at site.

In researchers observation since there is a provision of safety officer who are always visiting at site to supervise the implementation measures of safety so there may not be so difficult to implement the safety measures.

Table 23 Absenteeism of workers in different months

Workers	No of days worked in different month in 2076					
	Jesth (27 working days)		Ashad (27 working days)		Shrawon (27 working days)	
	Male	Female	Male	Female	Male	Female
1		22		24		20
2		21		20		20
3		19		21		22
4		24		24		22
5		19		20		19
6		18		22		20
7		17		25		19
8		18		17		18
9	25		22		23	
10	19		24		22	
11	22		24		21	
12	16		22		17	
13	17		24		17	
14	13		22		22	
15	17		23		23	
16	23		24		23	
17	23		23		22	
18	17		23		25	
19	25		25		21	
20	21		24		26	
21	26		25		25	
22	25		24		19	
23	19		22		22	
24	22		24		21	
25	21		23		21	
26	16		21		21	
27	21		23		22	
28	22		24		19	
29	19		22		17	
30	17		20		21	
31	16		22		19	
Total days worked	461	157.78	527.81	171.58	487.69	160.31
Avg. days worked	20.0	19.7	22.9	21.4	21.2	20.0
Avg. Absenteeism/worker/months	7.0	7.3	4.1	5.6	5.8	7.0

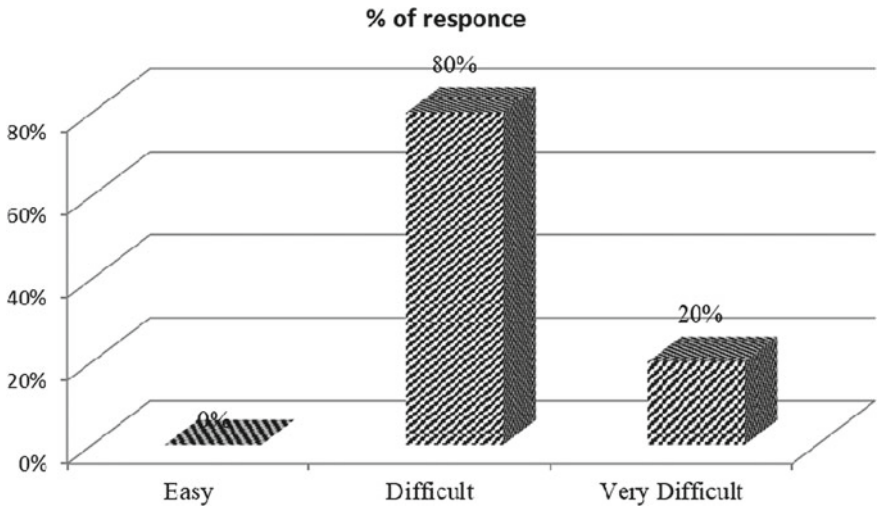

Fig. 16 Degree of challenge to implement safety measures at site

4 Conclusions

Fall hazards, mechanical hazards, physical hazards, and biological hazards were found as the major prevailing hazards. Fall from towers and conductors was found as the extremely risky hazards, other hazards like fall from scaffolding, tools and equipment's, unprotected edge, obstacles and slippery were found as the high risk hazards. Slip and trip, rock sliding, rock mass fall, snake bites, Heat and humidity, dead line pressure, dust, cold, electric shock, air pollution, job dissatisfaction, wages and leave were found as the moderately riskyhazards whereas noise, job insecurities, fall from ladders, chemicals, alcoholism, metal and paints, fall from roof, society and culture, management behavior were found as the low risk hazard.

Sign and signal, PPEs, preparation of safety policy, deputation of safety officers, construction of safety park to demonstration the use of safety equipment's, good housekeeping, provision of safety induction training, toolbox talks, safety briefing, barricades, provision of securities guards, provision of motivations, first aid facilities, separate toilets and bath rooms, good accommodations, safety auditing by contractor, third party inspection, availability of drinking water, separate storage of inflammable materials, continuous supervision by the safety officer were provided by the contractor to control the possible accidents at site. But there was the lack of implementation of other control measures like elimination, engineering, substitution and administrative measures for better safety of the work place.

It was found the average absenteeism rate of men was 5.6 days/worker/months and for women 6.63 days/worker/months. Till 15/09/2019 there was no any major accidents occurred at KGTCP so it is concluded that the safety measures adopted by the projects was found effective.

The concept of clients towards safety was found like; "the investment in safety is the un-necessary investment" because contract document does not includes the provision of safety budget to prevent the possible accidents. Although there was no any such provision of safety budget, the contract document tried to care about the safety by including the PPE items in BOQ. So to prevent, minimize and control the possible hazards at transmission line following recommendation had been provided.

Author Contribution The authors contributed all areas of entire work. 1st author contributed 40%, 2nd author contributed 35% and the third and corresponding author contributed 25%.

Data Availability The available datas are given in the text itself (all datas).

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest. S. Nithiyanantham.

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Femininizing a Masculinised Industry: From Altering the Demography to Transforming the Logic

Andrea Yunyan Jia

Abstract The construction industry is characterised by institutionalised masculinity which is destructive to not only women's participation and progression for a career but also men's safety, health and wellbeing. Deliberate institutional initiatives of increasing women's participation in construction effect a social engineering process to tackle this issue, which is disruptive to the long-standing organisational routines in construction projects. This chapter presents a review of recent institutional initiatives of increasing women's participation in the industry and examine their impact on the functionality of construction project organisations. The relevant institutional interventions and research were selected for an institutional analysis through a snowball sampling approach, starting from a recent Australian initiative to increase women's participation in trades. Five institutional logics are identified that are driving and legitimating the gender equality agenda: the masculinity logic, the market logic, the feminism logic, the humanity logic and the femininity logic. The review starts from a focus on 'women' and ends with a focus on 'femininity'. Key findings are: (1) Feminism in the current practice presumes a gender contradiction which mirrors the masculinity logic. (2) Professionalism, the logic of the work, is missing from the current gender equality discourses. (3) A distinction is drawn between the ideology of feminism and the general trait of femininity. (4) Complexity within feminism needs further study. The results suggest to foster the femininity logic through ungendered job roles and a caring, engaging and nurturing on-job practice, illustrated with three examples. The results suggest that the equality agenda move beyond gender politics to anchor itself in professionalism, embrace the femininity values more substantially in job design and appraisal that reward teamwork to engender a cultural change in the industry.

Keywords Institutionalised masculinity · Feminism · Femininity · Professionalism · Construction project organisation

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1 Introduction

The construction industry is a project-based industry in which women were either excluded or found a mainstream career path more difficult than their male colleagues (Salignac et al., 2018). Despite an improvement in gender equity over the past decade (CSC, 2010), women remain an underrepresented minority in the industry, particularly those working in trades constituting only 3.4% of the workforce in the US (BLS, 2018; Slowey, 2019) and less than 3% in Australia (CSQ, 2018). Furthermore, women's career paths were primarily excluded from the technical core of construction project organisations, persisting more around general and supporting roles. Even after decades of campaigning to improve gender balance in the industry, the percentage of women has not increased significantly, with the majority in supporting or administrative roles such as secretaries and human resources. To break the self-fulfilling cycle of the institutionalised masculinity, top-down institutional interventions, i.e., new policies and laws, targeted training programmes and campaigns, are necessary for at least a certain period of time to increase women's presence in the workforce to encourage a more female-friendly culture. Initially, such interventions were focused on attracting women into the construction industry by marketing the industry in schools and universities to bring in professional women by painting an attractive image of the industry. More recent campaigns have now turned their attention to the recruitment of women into the trades (Fig. 1).

Australia has started the social re-engineering process recently, with government and industry-led initiatives to increase the number of tradeswomen in traditionally male-dominated industries (e.g., Victoria State Government, 2016). The

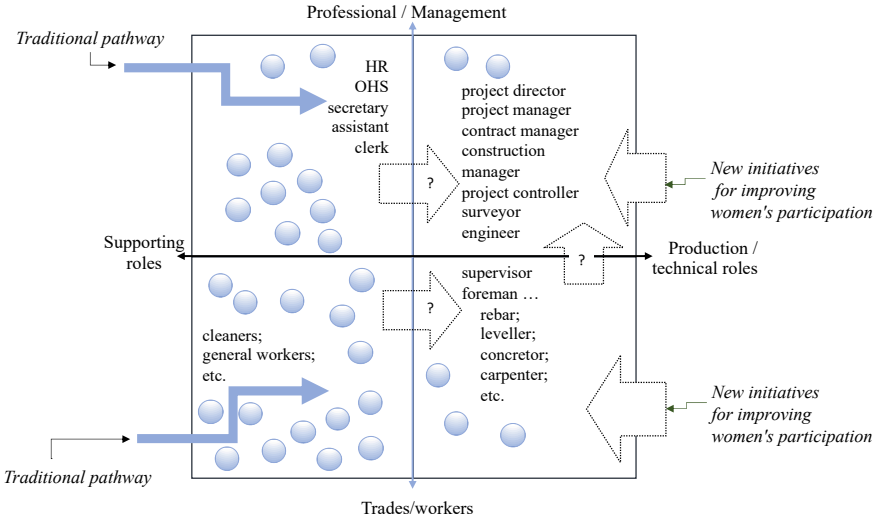

Fig. 1 Traditional women's career path in construction and recent industry initiatives

State Government of Victoria has developed a strategy to improve the attraction, recruitment and retention of women into the construction workforce, mainly the construction site or trade workers (BICC, 2019). Solutions out of existing research and policies have a focus on the 'fit' between the individual and the project organisational context. 'Fit' can be improved through either aligning individual capabilities with the existing context of the industry; or altering the work context in the project organisations to accommodate the otherwise 'unfit' individuals (Whittock, 2000). In practice, the former is achieved through women's training programmes, the latter through deliberate workplace policies or recruitment strategies. The institutional interventions kick off a social re-engineering process, i.e., altering behaviours by changing game rules (Hakim, 2006). Existing routines of project organisations are disrupted by either the new policies or the outcome of such initiatives, which need to be understood and carefully evaluated. This chapter aims to review relevant research and practice that can inform institutional interventions as such, from which to analyse how this social re-engineering process may impact the current project organisational practice and where it goes. The review leads to a deeper reflection on what defines a 'woman' and what is femininity, from which future institutional interventions may be informed.

2 Research Protocol

The research was conducted with a critical review of literature that outline existing institutional interventions on gender inclusivity and diversity in the workforce. The selection of research papers and documents adopted a snowballing approach, starting from the latest *Victoria's Women in Construction Strategy* (BICC, 2019), identifying compatible institutional practices and relevant literature by the key ideas in the document. Emerging but underexplored issues are reviewed through a search outside of the construction field. Five major discourses are identified, which helped focus a further search of literature to confirm and interpret these ideal types. The following sections present the findings of the review.

3 Results

3.1 Five Logics: Why, and Therefore, How?

In a review of the research and practice in the construction sector, five institutional logics are explicated regarding women's participation and their legitimacies, and as a result, their subsequent approaches to engaging stakeholders and change. On this basis, I analyse how the construction project organisation (CPO) routines are disrupted by the institutional practices.

3.1.1 Discourse 1: The Masculinity Logic

Institutionalized masculinity is the characteristic of the 'traditional' organisational routines and culture in construction projects and the industry. The masculinity logic is underlined by a belief that some occupations are deemed to be 'too dangerous' or unsuitable for women (Dainty & Lingard, 2006: 108, citing Gutek, 2001). The resulted practice is to exclude women from core technical works or limit their participation in the supporting roles only. The traditional CPO routines are built on these assumptions and stereotypes. Paradoxical factors that hinder women's entry and functioning in construction projects is the informality of the recruitment process (Fielden et al., 2000) and the rigid formalisation in work demands (Dainty & Lingard, 2006). Underlining this paradox is a masculinity logic, by which the informal recruitment norms in the industry attract and select those who resonate the pattern of interaction and those who are within existing social networks; the project organisation's structures and routines reflect the functioning mechanism of the current work population. Dainty et al. (2000) demonstrate that the formal structure in the organisation 'favoured male career patterns and needs' (p. 245), while informally in job appraisals, male managers in using their job discretion tend to underestimates the performance of their female subordinates (see also Poleacovschi et al., 2021). Informally, the masculine culture poses significant distraction to women who have to spend much time and energy to cope with harassment, discrimination and exclusion in a counterproductive environment while men are making their progress (Poleacovschi et al., 2021; Watts, 2009). The informal norms and cultures in the workplace such as sexism and work-life conflict are found to be barriers of women's career progression. Embedded in a paradigm of worshiping 'the strong', masculinity effects a victim-blame culture, which tends to legitimate a range of workplace health and safety issues such as bullying or slavery. Note, this logic is not exclusively upheld by men but also held by women. The gender stereotype is being applied by both men and women in assigning/expecting tasks and roles, offering support and exercising control. For example, King et al. (2019) found that the stereotype that women are good at looking after details, when applied by either male or female, can result in women being overwhelmed with administrative tasks when they are far more qualified to do the technical work. From an individual career perspective, Dainty et al., (1999: 353) found that women's careers would not be compatible with men's 'until the male culture of the industry has been moderated'. They went further to suggest that women not to start a career in the industry "unless steps are taken to moderate its exclusionary and discriminatory culture" (p. 239). After years of institutional interventions and campaigns, such stereotype persists (Baker et al., 2019; Poleacovschi et al., 2021).

3.1.2 Discourse 2: The Market Logic

Approaching construction projects and firms as an economic phenomenon, the market logic discourse legitimatises women's participation as to solve the issue

of labour and skill shortage in the industry. This is argued with business cases in order to engage the employers to hire more women into projects and firms (e.g., UN Women, 2018; Women into Construction, 2018). As early as 1994, it was observed that craftswomen were generally more reliable, producing higher quality work and free from alcohol abuse compared to their male counterpart (Fielden et al., 2000: 117, citing a personal correspondence with V. Bioko in 1994). More market-based business arguments include: (1) there is overall a shortage of labour in the market; (2) it enables selection of better talents from a larger labour pool; (3) a diversified workforce can reduce training cost; (4) a diversified workforce liaise better with the client's organisation which is likely to have diverse kinds of people; (5) it brings a better organisational reputation to attract better talents; (6) it gives you a committed workforce for quality deliverance; (7) more innovation.

In the market logic, women's participation is legitimated as a backup labour pool, which presumes the traditional hierarchy; the workplace culture remains traditional, too. With unchanged gender stereotypes, the participation of women disrupted the all-boy culture in the workplace and male code of behaviour, manifested in men 'feeling embarrassed' for not knowing how to deal with women as equal colleagues. For example, Fielden et al. (2000: 118) reported that when women surveyors joined office chat or lunchtime drinking events, their male colleagues felt inhibited such that the socialisation activities became a waste of time for them. The inherit risk in the practice of this logic is that the recruited women find it difficult to gain legitimacy in the workplace. Without a systemic change, such strategy has an effect of alienating the recruited women, which, in the worst case scenario, was taken advantaged by unethical employers to gain autocratic control over their employees. As reviewed and reflected upon by Dainty et al. (2000), women entering through this gate have found themselves lacking in career progression resulting in their ambitions being frustrated and thus sought to exit the sector. Thus although the campaigns in the 1990s for attracting women into the construction industry had successfully increased the number of women joining the construction workforce, retention was found difficult (Dainty et al., 1999, 2000). This is because the campaigns did not consider the holistic institutional environment, where masculinity was materialised in the organisational structures and processes in the industry, against women's career progression.

3.1.3 Discourse 3: The Feminism Logic

The feminism logic is a quest for gender justice by fighting for equality and right for participation (Watts, 2009). Here the term 'feminising' is often used to literally mean the increased number of 'women' in non-traditional occupations (Whittock, 2000). In fighting for a 'territory' for women in the traditionally men's territory, many women's associations in the construction industry are trying to foster a network among the women (e.g., Australia's National Association of Women in Construction, Trades Women Australia, etc.). Australia has synthesized the research and practice experiences from the pioneering countries and encapsulated the challenges that women faced in the masculinized work environment in one concept 'gendered violence'.

A Gendered Violence Research Network (GVRN) was established in 2001 based on University of New South Wales (Suchting et al., 2001-present). More recently, gendered violence is defined as an occupational hazard, with training programs and cultural change programmes developed to help women to define the problem and cope with it (e.g., BICC, 2019). These programmes enable women who are lack of personal network in the industry to be able to anticipate and cope with the informal side of the workplace.

From the 2000s, there has been a growing volume of research in work-life balance (WLB) in the construction workforce. Dainty and Lingard (2006) suggest an alternative project management model to organise the construction work around a workforce that put domestic responsibility a necessity and priority, from which to organise the work around family needs. Flexible work arrangement had been developed over the past decade in project organisations to accommodate domestic responsibility and improve work-life balance as solutions to the women issues. They predicted that firms will use their WLB policies as a strategy to attract female employees, which has become a reality in many workplaces in Australia including some construction sites. In recent years Australia sees more 'women-applicant only' job advertisements, including some major construction sites. Job advertisements 'WOMEN WANTED!' are posted outside of construction sites offering promises of flexible work arrangement. These initiatives have indeed made a difference to the gender demography in the industry. The disruption here is the traditional men's territory.

On critical analysis, we may see this line of studies particularly in the Australian context assumes a 'normal woman' in a domestic caring role in a traditional family structure, therefore legitimates the time for family caring duties in work arrangement. Empirical studies at this stage reflect the feminism logic which tends to discourse women as victims who are "forced to work long hours" or "forced" to conform to industry norm. When this becomes the dominant logic materialised in organisational routines, it brings a side effect of illegitimating the other lifestyles that fall out of the 'normal woman (and man)' template. Individuals who loved their job and enjoyed working long hours, regardless they are healthy or not, were treated as pathological (Lingard & Francis, 2009: 29–31). What is inadequately addressed so far is that a growing population in the workforce are not living in a traditional family structure, but enjoyed their work and its professional community where their personal identities are constructed upon (Hakim, 2011). Therefore the WLB knowledge helped negotiate the work arrangement needed by some women, but is associated with a risk of stereotyping the others (including men) who do not fall into its assumed lifestyle and family structure. This leads to a further inquiry: who are 'the women' that we see as legitimate to deserve the equal rights? Or, what defines a 'woman' that worth our inclusion?

An unexpected effect is that the institutionalization of feminism is often materialized through more prescriptive workplace policies and programs, which provides protection against gendered violence and excessive work demand, rightly; however, the prescriptive rules and their practice enact managerialism which is in competition with professional logic in the workplace. This is because proficiency in using such rules are not necessarily coupled with professional competence at work. Chances are

that self-interested people use the rules as political weapons to eliminate competitors within the work team, which risks compromising organisational performance on its core business. Indeed, an early review on European practice found that such social engineering approach had *reduced* gender equality (Hakim, 2006: 284). Thus, the instituionalisation approach of feminism is more of a reactive approach which presumes gender contradiction and mirrors the masculinity logic. It does effectively change the gender demography at different levels of the organisation, but not necessarily achieve its quest for justice and equality.

3.1.4 Discourse 4: The Humanity Logic

A humanity logic is defined here to categorise recent research insights that problematise the gender binary and attend to the diversely constructed individual identities in construction and the commonalities of humanity across gender identities. Reflections on masculinity have been carried out in recent years. A few recent studies suggest that the institutionalised masculinity in the construction industry is self-destructive to men, which is manifested in their denial of weakness, leaving them vulnerable to safety risks, mental health and suicide issues among site-based personnel. The ideology of masculinity has a self-restrictive power to stop the men from seeking help in times of weakness and difficulties, as exposing one's weakness is 'shameful' both internally and externally (Kotera et al., 2019). Furthermore, a growing volume of knowledge in gender equity research emphasizes that institutionalized masculinity affects the workforce as a whole, beyond the gender binary (Collins, 2015).

Review in the previous sessions reveals a common assumption among the masculinity, the market and the feminism logics in the gender equality event chain, which is a gender binary associated with a dichotomy between 'work' and 'life'. However, Chan (2013) suggests that construction is a highly homo-social context, which could provide a context for homosexual contact which generates another gender hierarchy among the men (Connell, 2005); while some highly skilled tradeswomen were labelled as lesbian which was not necessarily the truth. The finding unveils that masculinity has become the identity of construction work itself; while individual sexuality is socially constructed based on the perception of one's work expertise. Poleacovschi et al. (2021) found the engineering expertise is a more possessive element in male engineers' professional identity than in women engineers'. So here is a gender-identity paradox in relation to work expertise: if one is identified as a woman, she is perceived to have less professional expertise than she has; if she does demonstrate a high proficiency in construction work, she is defined as a non-women. Vice versa on the social construct of men's identity. Such insights take the equality agenda beyond the politics between two genders to understand how the nature of the work defines an individual identity. A future research area to be explored would be individual work and non-work identities part of which is gender identity (Ramarajan & Reid, 2013).

Research has also looked into change and complexity within masculinity. George and Loosemore (2019) in their recent research on Australian site supervisors find

that the masculinity ideology in the construction industry has changed to be more inclusive and less hegemonic. This study offers an explanation to the languages and behaviours that constitute masculinity on site as a work-based identity constructed against the high risk heavy manual work context. We thus learned empathy for the equally stereotyped men, reflecting on the feminists' reactive approach, which perhaps has over-criminalised the other gender at work. These recent insights suggest a shift of focus from blaming masculinity to treating the root cause, and clarify that the ultimate purpose of the equality, diversity and inclusion agenda is for improvement of humanity as a whole.

Deducted Intervention: Professionalism Ungendered

The research results categorized under the humanity logic are more about problematising the gender binary and understanding individuality and complexity in-depth. They have not yet come up with any solution. However, they bring to light how the work itself is an essential element of individual identity of this occupational population that indicates a solution. As discussed under the 'feminism logic' section, the assumed work-life dichotomy underpinning the WLB research and policies sees 'work' as a demand and exploitation for the workers, while a work environment that leaves enough off-work time will benefit individuals. The problem with this assumption is that people do not necessarily feel happier without work when work is so essential an element of one's identity. The WLB literature correctly identified many sources of women's (and men's) job stress are from the family/relationship issues in one's personal life domain, which, however, does not necessarily resolve by allocating more time to it. The nature of the work can be either demanding or fulfilling, or both. There is the work '*performed solely in order to gain a living*', and there is the work performed for '*the pleasure of self-fulfilment it provides*', through which life is beyond '*a life of toil*' (Freidson, 2001: 107, Haworth, 1977). This brings to sight a missing logic in the debate of gender equality so far, professionalism, which suggests a distinction between the 'gender equality' for a general public and the 'gender equality' in a work context. The latter is more concerned with ways of organising the work and project routines where the nature of the work cannot be ignored. The accommodation of domestic responsibility is a matter of time allocation in job design and human resource management practice in the project organisations; while to accommodate people of different identities and interaction styles is a more subtle issue to be addressed in social engineering the project organisational environments, and this is vital for team integration and project performance as well as individual fulfillment at work. In the context of construction project organisation, the problem is ultimately about individuality, professional competence and teambuilding. Future research may proceed to explore how professional expertise and professional ethics are gendered, as a base for a new, ungendered professionalism as a common ground for the construction workforce.

3.1.5 Discourse 5: The Femininity Logic

Having gone through masculinity mirrored by the feminism practice and a problematised gender binary, it is necessary to revisit what is femininity. From early studies some essential features of femininity may be gleaned to understand how it worked for good in a masculine environment. The presence of women in the male-dominated workplace was found to have resulted in a less aggressive workplace culture, as men felt obliged to behave as 'gentlemen' to help the women (Fielden et al., 2000: 117, citing EITB, 1987). In this scenario, the women were not fighting for equal right, but simply exist in the being of a woman, a role of 'weakness' in need of help. The presence of a colleague in a female being awakened the gentleness within the masculinity and turned the competitive culture into a collaborative culture. It takes someone 'dare to be weak' in the competitive environment to transform the work culture, and this is what is missing in the institutionalised masculinity which the feminism approach does not provide. Femininity is not about gender or sexuality, but a way of doing things, or, a set of cultural values explained by Hofstede's (1980, 2001) masculinity/femininity cultural dimension, as summarized in Table 1.

Table 1 also helps clarify the difference between the ideology of feminism and the general trait of femininity. The contrasting values suggest that the feminism approach to institutional change, as reviewed earlier, espouses the values of masculinity rather than those of femininity. Thus femininity is not a distinctive logic but a mirrored masculinity in the current institutional practice. In contrast, femininity is not about 'who' but an alternative and complementary approach of doing things. It does not set women in competition with men but construct a work logic from the traditional caregiver's role. The femininity logic is embodied in the problem-solving practice of engaging, sustaining, fostering, aligning, reconciling and nurturing. Islam et al. (2017) analysed the role of women taking leadership in the post-disaster re-building projects in rural area and suggest that the inherent vulnerability in a feminine identity underpins a more empathetic approach to organising and teambuilding in disaster responses (United Nations, 2009). It by accepting and acknowledging their own weakness that the project leaders are inclined to run the project organisations in a community logic rather than a market logic, resulting in organisational resilience.

Table 1 The masculinity/femininity cultural values (Hofstede, 2001; Hofstede & Hofstede, 2005)

Masculinity (as is feminism)	Femininity
Ego oriented	Relationship oriented
Respect for the strong	Empathy for the weak
Winning the competition is important	Collaboration is important
Individual achievement (money and things) is important	Network (life and people) is important
Assertiveness is good	Modesty is good
Failing is a disaster	Failing is a minor accident

Similar effect is found in cases where men perform traditionally women's job. For example, in Hong Kong, the MTRC set up site nurse roles in its construction projects, all of which were filled by men. The site nurses were looking after the workers as well as organising fun activities to engage the workers to be mindful about their own health and safety at work. In that case, the site nurses are performing a more holistic role in both health-caring to the workers and management/execution of the OHS programmes on site. In this role they still have participation and experience in the technical core of the project delivery process, and therefore prospectus and competency for career progress in the construction industry.

Another exemplar case was observed by the author from the practice of a Safety Advisor in a megaproject in Australia. Rather than positioning himself as an inspector to enforce the rules, the Safety Advisor worked with the workers more as a care-giver and a personal coach in his routine inspections. When a worker was found out breaching the company regulation at work without wearing safety glove, the immediate response of the Safety Advisor was to take off his own gloves and give them to the worker. There were no words of blame but complementary inquiries on their needs at work.

A third case was observed from an experienced regulator's inspection on a construction site in Queensland, Australia. When came across contractor's unsafe practice on site, the regulator did not respond by issuing a red tape, but discussing with the site manager to suggest recent innovations in construction methods that could help eliminate the risk of the unsafe practice.

These cases help distinguish femininity from feminism and makes it clear that the latter is centred on a political interest group ('the women'), which presumes a gender segregation and contradiction; while the former is a personality trait or a set of cultural values which does not segregate by gender or sexuality. To draw an analogue from the Scripture, the feminism approach is a reaction of a natural human being, i.e., "*eye for eye, tooth for tooth*" (Deuteronomy 19: 21), projecting a counter-force to masculinity. Femininity may be analogized to a scenario from Matthew 5:41—"*Whoever compels you to go one mile, go with him two*", being complementary to masculinity, which has a natural power to transform it into a teamwork.

Imagine you are back in the first Century walking on the street. A Roman soldier forcefully catches you and forces you to carry his heavy gears for a mile. In contemporary terminology, this is an act of bullying. In an reactive response, you stand against the bully and call your friends to fight for you—there you are practising the feminism logic. Alternatively, if you are embedded in a femininity logic, you perceive this is an act of seeking for help; you attend to his request with care, take over the load from his back, carry it and walk with him for the mile he has asked. By the end of the mile you say, "Look, you still have a long way to go with this heavy load and I have some more strength to help you. Let me go an extra mile with you."—there you are practising the femininity logic. Now you are voluntarily carrying for him his load for an extra mile—it is an act of teamwork. In the second scenario, there is no assumption of contradictory but extended compassion which has transformed a bullying event into a teamwork. There is an identity shift, too: the Roman soldier's identity is transformed from a 'bully' into an equal teammate of you; your identity

is transformed from a 'victim' into a care-giver and a team leader. Thus the weak *is* the strong. The transformation is not a psychological manipulation but a natural outcome of the femininity logic that you are embedded in. Because you are embedded in it, your attention is exclusively focused on the work, the other person's need and what you can do to help him out. There is no calculation of fairness, no resentment or revenge—these are simply not in your repertoire. In your first mile, both the masculinists and the feminists see you as a victim of masculinity—the masculinists see it a victory of the strong who will continue to excel in power competition; the feminists see it the victimisation of the weak who needs to be patronized—only you know you are not playing their scenarios. In your extra mile, the femininity logic is made clear to all. Your extra mile rewrites the meaning of your first mile. The dominant logic is thus transformed; the presumed contradiction is dissolved into a collaboration. The masculinists can now perceive your strength by which you are legitimated to worth their respect, as a friend and partner not an enemy or competitor. The feminists now feel betrayed, get cross with you, and may even go further to attack you—simply because you have collapsed the contradiction upon which they build their whole ideology and their existence. Throughout the event, your mind in a femininity logic is shielded from the question of 'who' reigns or what is 'my' right, but has a single focus on teambuilding.

As a cross reference, Lao Tzu's (l.c. 500 BCE) analogue between water and leadership offers an authentic explanation of the femininity logic defined in this chapter:

The best of wo/men is like water.
Water benefits all things, and does not compete with them.
It dwells in the lowly places that all distain
- wherein it comes near to the Truth.
In his dwelling, he loves the lowly earth.
In her heart, she loves what is profound.
In his relations with others, he loves kindness.
In her words, she loves sincerity.
In governance, he governs with peace.
In business affairs, she has ability.
In his actions, he acts in sensible timing.
It is because she does not fight that she is free from evil.
- Lao Tzu, 500s BC: Tao Te Ching
(adapted from the translation by Lin Yutang, 1948)

Individual experience of practising a femininity logic may find a description in the Scripture as follows:

by pureness, by knowledge; by longsuffering, by kindness;
by the Holy Spirit, by love unfeigned; by the word of truth,
by the power of God;
by the amour of righteousness on the right side and on the left;
by honour and dishonour, by evil report and good report:
as deceivers, and yet are true;
as unknown, and yet well-known;
as dying, and behold, we live;
as punished, and yet not killed;
as sorrowful, yet always rejoicing;
as poor, yet making many rich;
as having nothing, yet possessing all things.
- II Corinthians 6:9

From a process perspective, such disruption cannot be a top-down social engineering process. It is embedded in personal convictions of individual personalities. The driver for the disruption of the femininity logic is a few seeds of individual personalities who are willing to pay the cost of 'being seen as weak' and able to persevere. It starts spontaneously from individual values and practices to foster a cultural change bottom-up. Institutional intervention will be an outcome of the cultural change, materialized in ungendered job roles and task assignment, job appraisals that value teamwork more than individual achievement. This process happens much slower than the top-down social engineering approach but it happens from a cultural change and once it happens, it is a solid reality rather than an ideology.

3.1.6 Summary of Findings

The five logics, their resulted interventions and the nature of their disruption to the CPO routines are summarised in Table 2. The masculinity logic underpins the traditional practice. The market logic and the feminism logic underpin our current practice for gender equality. The humanity and the femininity logics are our hope for future.

Table 2 Five logics and their corresponding approaches and disruptions to project routines

Logics	Interventions	Disruption to CPO routines
Masculinity logic	Exclude or patronise women	No disruption to traditional CPO
Market logic	Recruit women into a masculine workforce	All-boy culture and socialisation routine disrupted
Feminism logic	Fight a territory for 'the women' through prescriptive institutions	Men's territory disrupted
Humanity logic	A renewed, ungendered professionalism	Existing work ethics and code of practice disrupted
Femininity logic	Empathizing, sustaining, caring, nurturing, engaging, fostering	Organisational structure/process disrupted; ungendered job roles; alternative job design/appraisal; team integration

4 Discussion

4.1 Complexity Within Feminism

Historically, the concept of feminism has been defined in various ways and scopes. The feminism logic defined in this research is a narrower one, focusing on the logic underpinning the institutionalized practices of gender equality in the past few decades. On this basis, one of the contributions of this research is to draw a distinction between feminism and femininity. More rigorously, the result suggests that the feminism logic is not a distinctive logic from the traditional masculinity logic. Rather, it is more of a mirrored masculinity logic. It is centred on "women", yet the complexity within women's world would keep one wondering "*who are legitimated as 'the women'?*", this is an area of interest for future research. At least three types of subcultures exist among women in the workplace: a family logic, an administration logic and a professional logic. Misfit between the individual and the subculture of the work team leads to the same result as a feminine person finds her/himself struggling in a masculinized work environment. So the feminism logic finds its manifestation in practice an island-building approach, which must be applied with caution; and an awareness that it only works on the basis of a team of shared vision, complementary skills and sensible management.

Research on sexuality minorities in the construction field is moving the field beyond the politics between women and men, and takes us to examine the many other latent criteria in people's mind that are dividing and categorising people, and underpinning how people treat each other. A recent theory shows that people are disadvantaged by 'associated categorisations', one of which is occupational stereotype (Hall et al., 2019). Thus the problem with sexism, as with racism, is not about discrimination, but about simplistic categorisation of people, arbitrary association between categories and attributes, and ignorance of diversity and complexity within a category. An awareness of one's mental categories of people and their attached attributes, and a healthy suspicion of one's assumption about

people, would help minimise the risk of stereotyping and work out innovation from better cognition of individual characteristics and potentials.

4.2 Roadmap: From Competing to Reconciling; from Island-Building to Teambuilding

The research effort of asking what women want in the industry, so far, are focused on attracting women into the workforce. A further step on the retention and progression of women's career in the project organisations takes further research on how women function at work (Sojo & Wood, 2012), which is not achievable without going beyond the gender binary to address the heterogeneity of individualities. A more subtle and substantial social re-engineering in the project organisational structure and process is needed to engage femininity in task design, job design, job appraisal and the project business. Particularly the job appraisal criteria in project organisations need to move beyond measuring individual achievement. Innovations in metrics for evaluating teamwork and engagement are needed to complete the social engineering cycle to make the right disruption happen.

The feminists' reaction against 'undermining women's achievement at work' is towards a perceived suppression from 'men'. It in effect mirrors the masculinity logic which assumes 'achievement' as the default way of progressing a career. Such criteria encourage individual competition and possession of achievements, consequentially undermine teamwork and jeopardise project performance, which is counter-femininity. The femininity logic, though espoused by scarcely few individuals, does not aim for personal achievement but rather focuses on fostering and nurturing people around, sense-giving to people's works and enabling others to achieve their respective potential. Such work needs to be recognised in performance appraisals to encourage teamwork and reduce destructive competitions.

The review thus suggests a 'fighting' mentality is not the solution for building a sustainable gender-balanced team that can learn and grow together. Effective leadership embraces conflicting parties or ignore the conflict to focus on reconciliation and engagement, with a professional logic at the core of practice. An interesting example is the 2017 ARCOM conference, which put a significant number of women on the stage, probably owned to a few male and female committee members' initiation.

4.3 Methodological Issues

Methodologically, many studies suffer from taking women-only samples, leading to more or less egocentric results. The problem is that if women have been disadvantaged in career entry and progression for more than a generation, the participants of the research may or may not have enough experience of the technical core job roles in the CPOs. Thus the findings risk reflecting outsiders' perception and projection of the work environment and what it should be, falling short of triangulated reality

and reliable evidence. The results need to be taken with caution when translated into social re-engineering strategies for altering the CPO routines. An exception is found in an early work by Dainty et al. (2000) which takes paired samples from men and women to examine the effect of organisational structure and process on women's under-achievement. Another recent work is found in Poleacovschi et al. (2021) which compares how much male and female engineers build their individual identities differently on their professional expertise.

Beyond a balanced sample and stories, social network analysis (SNA) as a methodology could be a promising approach to study on women's entry and career progression in CPOs and the construction industry. Rather than trying to boost women's career through an 'island-building approach', a healthy development might be achieved by an evolution (rather than revolution) approach through network development. Here a mechanical social network analysis would be of little help. The social network is to be applied more qualitatively against the structure of the construction community of practice context (Lave & Wenger, 1991). The analysis need to bring to sight the content and nature of the social connections, the identities of the people in the social network, and the evolution of the network in demography and structure over time.

Beyond a fighting mentality and an island-building approach, a more peaceful and viable path for women's participation would be similar to an ethnographer gaining access and acceptance in a cultural ethnic group: women are brought in and connected with a few gatekeepers of the existing work community, moving from peripheral to more central to be legitimatized as one of the members of the community of practice. A prediction of network change is illustrated in Fig. 2.

5 Conclusions

This chapter reviewed existing research and institutional practice on the gender equality agenda in the construction field with relevance to Australian current practice, as an output of a study undertaken when the author worked as a senior lecturer in the Faculty of Architecture, Building and Planning at University of Melbourne. The review identified five major logics that legitimate different approaches to construction project routines: the masculinity logic as the long-standing traditional culture; the market logic and the feminism logic which are the current practice for gender equality; the humanity logic which calls for a new ungendered professionalism; and the femininity logic which suggests a more substantial change bottom-up in structure, process and culture of the workplace. The five logics constitute a maturity model that works as a roadmap to guide research and institutional interventions for the gender equality agenda.

An important contribution of this chapter is drawing a distinction between the ideology of feminism and the general trait of femininity, exemplifying its materialisation in the construction field. Existing initiatives in the Australian construction industry are focused on women as a political interest group, although who are 'the

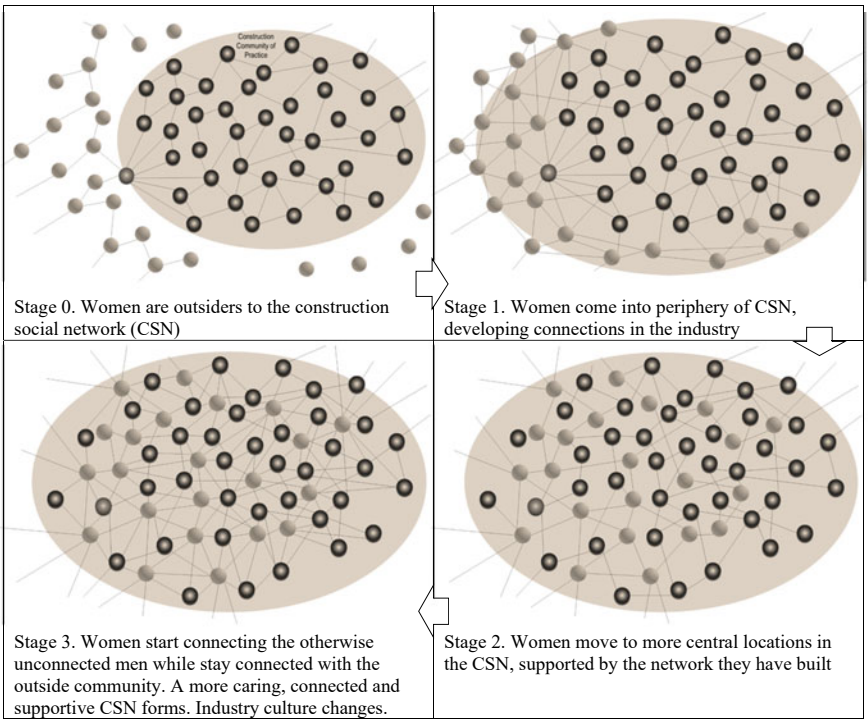

Fig. 2 Predicted pathway of women's participation in the construction community of practice

women' is open to interpretation. The ideology underlining these initiatives is built on an assumed gender contradiction, which mirrors the traditional masculinity culture in the industry. While femininity is more of a personality trait or a set of cultural values than a biological human category, assuming no gender dichotomy, and is embodied in individual problem-solving practice of engaging, sustaining, fostering, aligning, nurturing, and enabling others to achieve their goals. As for the practical problem of women's participation in construction, the research suggests it to be achieved not by 'fighting' the political category of 'men' but through a focus on teambuilding. If we are really serious about equality, diversity and inclusion in construction, we need to foster the femininity logic together with a renewed, ungendered professionalism and a focus on teambuilding. The disruption starts from a few seeds of individual personalities who are willing to pay the cost of being seen as 'weak' and able to persevere. Bottom-up, the seeds will foster a cultural change, which will drive a structural change in the organisations. This process happens much slower than the top-down social engineering approach but once it happens, it is a solid change rather than an ideology.

Five worthwhile future research areas emerge from the review, including: (1) complexity within the female workforce or sub-cultures of women entering and progressing in the construction project organisations, how different types of women

interact and construct legitimacies and therefore diversified pathways for participation; (2) the changing organisational dynamic when women's participation is increased and its impact on project performance; (3) process of the recruited women to gain legitimacy to be integrated into the existing team; (4) innovations in job appraisal for evaluating individual contribution to teamwork and engagement; (5) conflict or congruence between the five logics and the logic of the construction work itself (professionalism) in practice.

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Hazard Awareness in Stages of Real Estate Development

Rita Yi Man Li and Pak Chuen Leung

Abstract To understand the global research status in construction hazard awareness, this research studied articles indexed on the Web of Science by using the keywords "construction hazard awareness", "real estate hazard", "hazard recognition", and "urban renewal hazard". There were 2182 articles indexed on the Web of Science from 2011 to 2021. The US recorded the most considerable research on this topic. It published 530 articles with 11,149 citations, which is higher than other countries as double or more. Also, the US accounts for 24.3% of all the articles. China ranked second with 270 articles (12.37%), Italy ranked third (126 articles accounted for 5.77%). Other active countries in this area included the UK, Australia, and Germany. Regarding the highest citations institutions, the University of Pittsburgh recorded the highest citations (1143 times).

Keywords Hazard awareness · Urban renewal · Construction · Real estate

1 Introduction

As one of the largest employers worldwide, the construction industry plays a vital role in the global economy; however, it always records high accident rates and insurmountable accident compensation. Many accidents resulted from equipment failure, unstable load, and structure. Risk factors such as hazardous chemical hazards and falling objects coupled with short project completion deadlines, an increase in requirements, project complexity, economic uncertainty, and high business competition with low profit margins; new management approaches. Furthermore, construction practitioners rely on intuition and experience and tend to underestimate the

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dynamics environment. As a result, construction activities are high-risk (Xu et al., 2019).

Previous research found that cognitive psychologists believed that human error resulted from one or multiple catastrophes in three stages of the cognition process, namely hazard perception, recognition and decision making. Endsley's situation awareness theory proposed that when a person encountered a dangerous situation, precise and speedy decision-making comprised matching or pattern recognition, which required sophisticated schemata formation, and prototypical situations, eased the decision-making process. Hazard recognition largely depended on workers' ability to detect hazards. Thus, safety training is usually devoted to equip workers with the skills needed to recognise and manage dangers (Li et al., 2019).

To improve construction safety, there is a need to enhance safety management and identification of the construction workers. Identification of the worker's physical health and assessment workers' behavior on the construction before working. Meanwhile, to raise workers' safety awareness and workers' ability to detect hazards related to accidents prevention, some safety awareness lectures or examinations required by law for the construction workers could improve hazard identification and risk perception.

In a research that interviewed forty construction workers who came across accidents over the past 5.5 years revealed that many accidents could be avoided if workers have a high level of hazard awareness (Li et al., 2018). On the other hand, construction companies can significantly reduce risks through risk assessments, provision of method descriptions, and written health and safety policies and procedures. Communication and training on health and safety in the workplace were keys to health and safety risks. Okoro et al. (2017) suggested that education and training increase the ability of labourers to gain more knowledge from practical on-the-job training sessions and increases productivity. Thus, training and education of the workforce should be continuous and satisfactory.

The safety and training of construction workers remain a significant issue in the construction industry. More effective safety training must be carried out to improve workers' safety awareness. Promote education and training improve the ability of workers to gain more knowledge. Ahn et al. (2020) found two means of efficient training, which include the conventional lecture and the 3D Building Information Modeling simulation, reflecting the hazard condition of the actual site. An experiment is conducted in which the two types of training are implemented and assessed by testing trainees' understanding. The workers trained via BIM simulation showed a better understanding than the group training conventionally. Also, a survey was conducted targeting safety managers, in which the workers evaluated the lifelike quality of the training, active learning, and enjoyment that each of the training methods. The results found that an innovative method using virtual reality was more effective than the conventional lecture method (Ahn et al., 2020).

Project management personnel and site supervisors are responsible for supervising the construction plan and monitoring the project's progress. They play an essential role in ensuring the safety of site workers. To effectively fulfil this responsibility, site

foremen must have risk assessment and site safety management skills. To improve workers' awareness of occupational safety and health and cultivate safe working attitudes and behaviours.

2 Identification of Construction Casualties and Risks

Shafique and Rafiq (2019) studied the construction accidents in Hong Kong, fall from height ranked the most common cause of mortality on sites, followed by contact with electricity or electric discharge and striking by a falling object.

The construction industry could use advanced technologies in the construction industry to reduce the number of accidents. Adopting advanced technologies such as sensor-based technologies, robotics, and automation in the construction industry could also improve safety. These cutting-edge technologies have the potential to improve safety.

The most important factors affecting the development of accidents in the construction industry are divided into three groups according to their locations of construction works and their surroundings. The first group included the primary factors that were directly related to a construction site: the working environment, equipment, working methods, management, people, and construction products. The second group included the organisation's factors, such as the construction enterprise. It included organisational structure, enterprise management, management staff, safety culture, organisations, associations, and technical equipment. The third group included factors the city/country's factors and could be divided into the following subgroups: national economy, education, legislation, and society (Hoła et al., 2017).

3 Data Sources and Research Methods

3.1 Data Sources

To understand the global research status in construction hazard awareness, this article collected articles indexed on the Web of Science by using the keywords "construction hazard awareness", "real estate hazard", "hazard recognition", and "urban renewal hazard". There were 2182 articles published from 2011 to 2021, and articles' information such as author, publication organisation, abstract, keywords, publication year and references were analysed by VOSviewer.

3.2 Research Methods

A bibliometric analysis represents an understanding that offers a transversal overview and the current state of research on the topic of interest. It is a statistical and quantitative analysis that aims at identifying the scholarly impact and characteristics of publications within a specific research field, which could provide useful information to researchers involved in the development of research strategies to address the health issues (Iftikhar et al., 2019), study the impact of economic development on construction safety (Luo et al., 2022) and tourism research (Zeng et al., 2022).

This paper used VOSviewer to create a map for analysing the co-occurrence of keywords in hazard awareness in the construction industry over the past ten years. VOSviewer is software for creating network-based maps to explore the literature data relationship. The VOSviewer feature can be summarised as map creation based on network data and map viewing and exploration. A map can be created based on an existing network, but it is also possible to build a network first. The VOS reader can be used to build networks of scientific publications, scientific journals, researchers, research organisations, countries, keywords, and terms. Elements of these networks can be connected through co-authorship, co-occurrence, citation, bibliographic linkage, or co-citation links. Bibliographic database files and reference manager files may be provided as input to the VOS viewer (Eck & Waltman, 2020).

4 Overview of Construction Hazard Awareness

4.1 Study of Co-authorship

Inputting the full-text document records from Web of Science imported into VOSviewer, and set the authors under co-authorship analysis and the minimum number of documents of authors as 2. In the cluster view, a total of 5 clusters, 46 key nodes, and 71 total link strength. The representative author's research on hazard awareness in construction, Alex Allbert, and Heng Li were cited more frequently (Fig. 1), and the co-citation frequency was more than 28. Also, the overlay view shows the time series of this research from 2011 to 2020, from dark blue to yellow. Alex Allbert is the most representative author. He quoted Inductive data from the article's research in 2014–2016 (Fig. 2 bottom left corner) by Martin Skidmore, Greg Chan, Xincong yang, Fenglai wang, and Hong Zhang. Also, Alex Allbert's articles have been cited by many scholars.

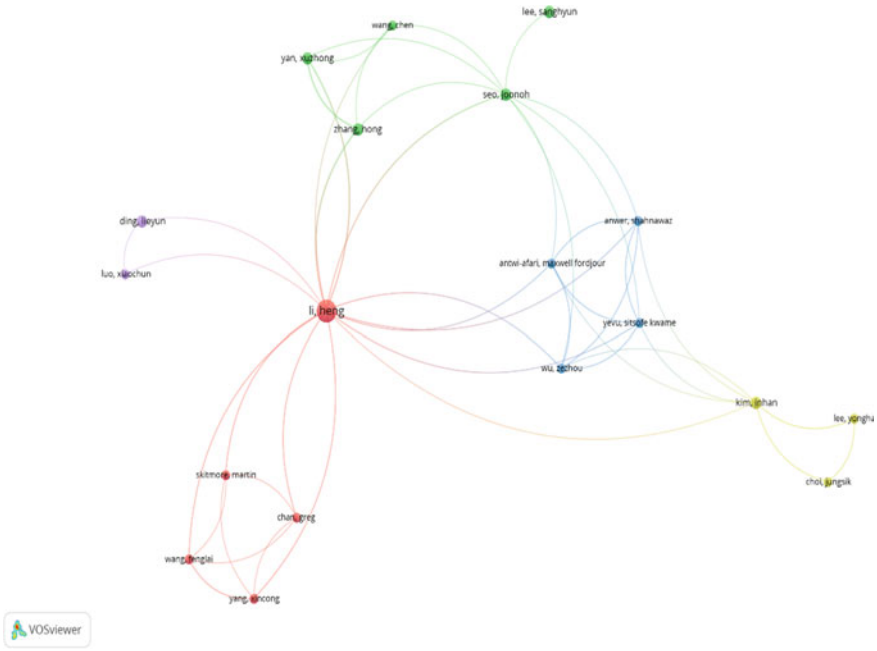

Fig. 1 Authors cluster network visualisation

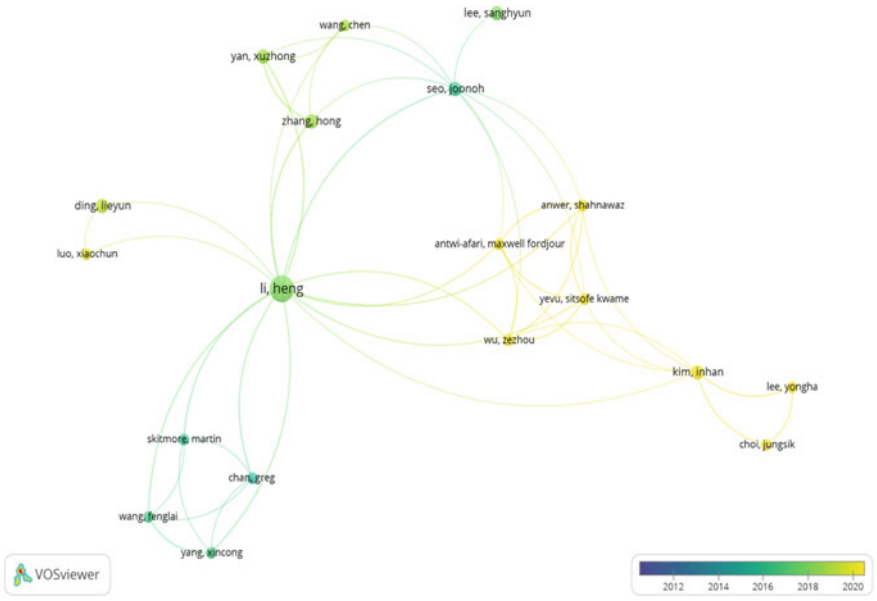

Fig. 2 Authors cluster overlay visualisation

4.2 Co-Authorship Analysis by Countries

We imported the records from the Web of Science website database into VOSviewer and drew the map between different countries. Figure 3 shows the minimum number of documents of a country as six from the 98 countries. Forty-six countries met the thresholds (Fig. 3). The US recorded the most significant research on this topic, with 530 articles with 11,149 citations by others, which was higher than other countries by double or more. Also, the US accounts for 24.3% of the total weight number of articles. China ranked second with 270 articles (12.37%), Italy ranked third (126 articles accounted for 5.77%). Other active countries in this area included England (124 articles accounted for 5.68%), Australia (83 articles accounted for 3.8%), and Germany (81 articles accounted for 3.71%).

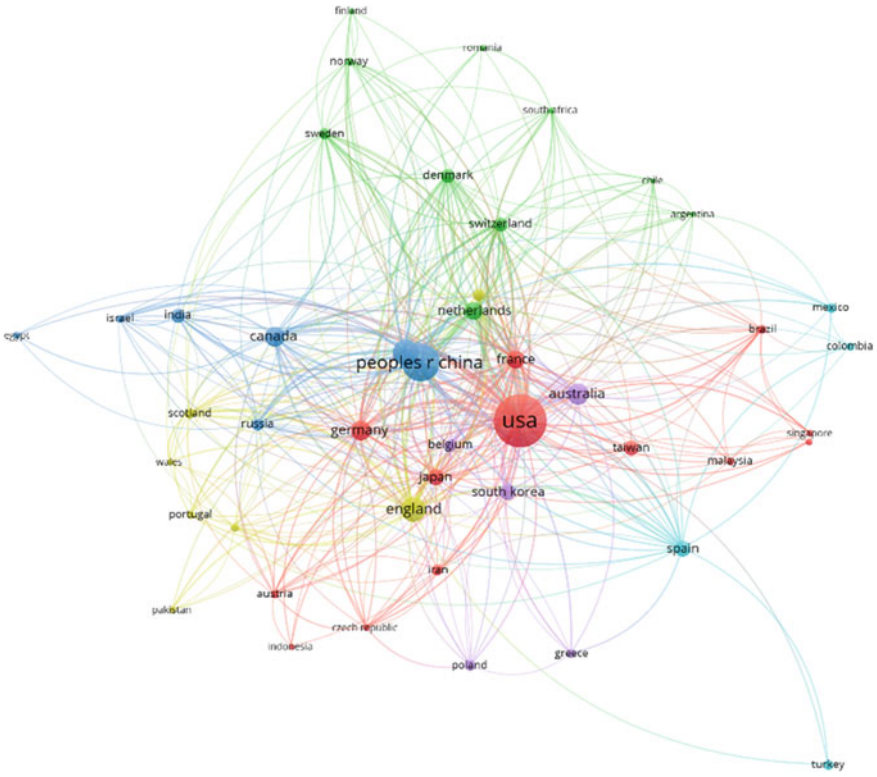

Fig. 3 Countries co-authorship network visualisation

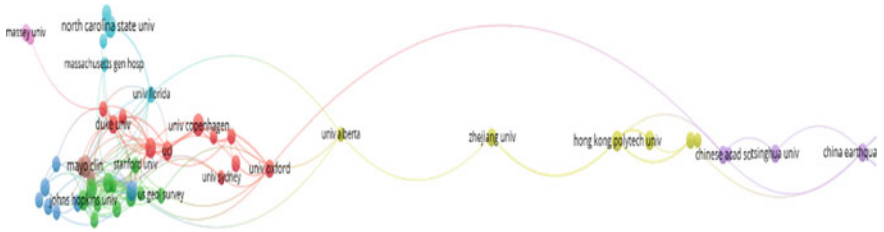

Fig. 4 Organization co-authorship analysis network visualisation view

4.3 Co-authorship Analysis by Organization

By setting the minimum number of documents of an organisation to 8 times, 57 out of the 2473 organisations met the thresholds (Fig. 4). The University of Pittsburgh has recorded the highest citations (1143 times). Mayo Clinic is the most issued organisation that published 20 articles on this topic. Followed by North Carolina State University published 19 pieces of literature, and Copenhagen University issued 18 pieces of literature. Figure 4 shows the network of collaboration.

5 Hazard Awareness in Construction Research

5.1 Research Trends

Table 1 shows the top 10 keywords with the highest co-occurrence. That is, frequency is more significant than 110 times per VOSviewer. The keyword "recognition" recorded the most significant number of occurrences. Others include risk, management, identification, model, health and mortality.

5.2 Hazard Awareness in Construction Co-occurrence Analysis

Figure 5 shows the clusters of research topics. Similar research fields are in the same colour, and the size of the label indicates the research weight. The blue cluster is a cluster of risks, with keywords like hazards, risk, vulnerability. The red cluster is the management cluster related to various management like health, risk perception identification etc. In the yellow cluster, it is mainly related to recognition, classification, prediction. The green cluster is related to mortality; keywords include survival, disease, risk factors, prognosis.

Table 1 Keywords for construction hazard awareness research

Ranking	Keywords	Co-occurrence
1	Recognition	216
2	Risk	211
3	Management	195
4	Identification	192
5	Model	177
6	Construction safety	174
7	Safety	138
8	Health	136
9	Hazard recognition	131
10	Mortality	119

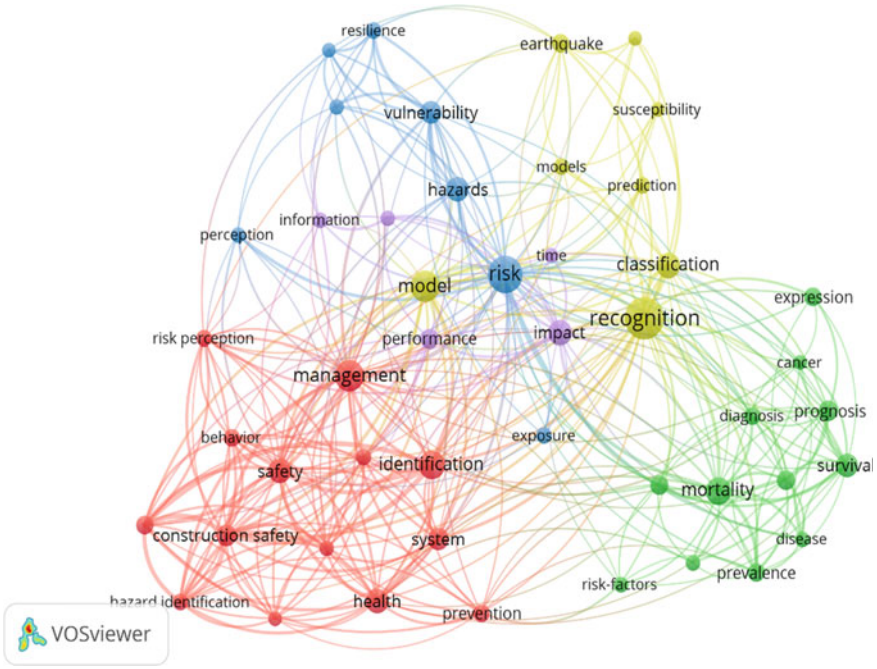

Fig. 5 Keyword co-occurrence network visualisation view

Meanwhile, Fig. 6 shows the research trend from 2011 to 2021 related to construction, occupational stage and urban renewal hazards. From 2011 to 2014, research on this topic was scarce, and there were no dark blue colour circles in Fig. 6. In 2015, more people conducted research on hazard awareness research. Most circles' colour

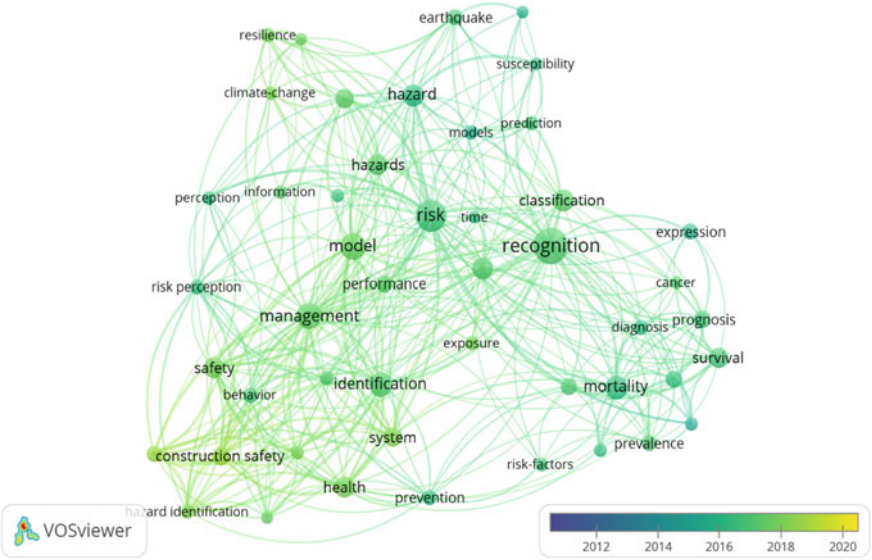

Fig. 6 Keyword co-occurrence overlay view

in Fig. 6 was green, which means most hazard awareness research in this area was published in 2016.

Meanwhile, the occurrence density (Fig. 7) shows the deepest part of the research, relying on the colour of each keyword is determined by the research density of that point. More centralised the colours refers to the research increases in number, the citations incline to dark or light yellow. The keywords of "recognition", "risk", and "management" etc. it is records the darkest yellow in Fig. 7, and it is the same result in Table 1. After being analysed using VosViewer, 5 clusters (red, green, blue, purple, and yellow) showed the relationship between one topic and another.

6 Conclusion

This paper conducted bibliometric analysis and visualisation tools through the VOSViewer and studied 2182 articles indexed on the Web of Science. Recognition, risk, management, identification, model, health and mortality were the most popular topics in construction, real estate hazard, and urban renewal hazard. Despite previous research suggesting that construction hazard awareness and safety could be improved by artificial intelligence, robotics, and 3D building information modelling (Li, 2018, 2019), these IT related topics were not research focus from 2011 to 2021. The US was the most productive in this period. The US authors had 530 articles cited by 11,149 times, which almost doubled the second country China (270 articles), quadrupled Italy which ranked the third (126 articles). Other active countries were

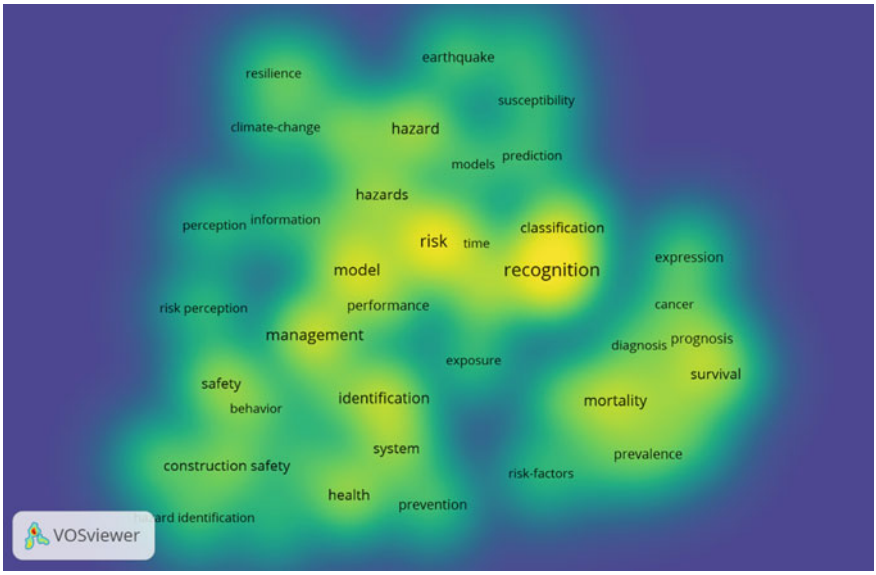

Fig. 7 Keyword co-occurrence density view

all developed countries. They included England, Australia, and Germany. Finally, the University of Pittsburgh recorded the highest citations (1143 times).

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Demystifying the Recent Trends and Advances in Safety Culture Research: A Systematic Review

M. D. Deepak and Gangadhar Mahesh

Abstract In the recent times, there has been a growing concern to improve safety management practices in the construction sector. In this regard, there is a need to improve "safety culture" as it plays a significant role in improving workplace safety conditions and is viewed as a comprehensive construct having possibilities of interventions at all levels of construction projects. However, the growing body of knowledge on safety culture research makes it difficult to have a systematic and comprehensive view of the subject. Towards addressing this issue, there is a need to systematize this body of knowledge with a comprehensive systematic literature review. The review is based on three-step methodology. First step aims at gathering suitable articles related to safety culture in construction sector. The second step presents the results of descriptive analysis on recent trends in safety culture research. Last step focuses on a detailed systematic review pertaining to definition, factors, and assessment tools that influence the level of safety culture practices. Results of this review help to uncover and provide a comprehensive overview of recent trends and advances governing safety culture research, and it can help academicians and practitioners identify fundamental influence from these published articles. Implications of the study emphasized that the study outcomes can assist researchers and practitioners to have consensus on industry-specific standards. Furthermore, this systematic literature review has helped to conceptualize safety culture, thereby highlighting the impact of external events and stakeholders interests in construction sector.

Keywords Safety culture · Systematic literature review · Construction sector

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1 Introduction

For the last two decades, there has been a rising concern among safety professionals towards enhancing safety management practices in construction sector (Luo et al., 2022). In this regard, there is a need to improve "safety culture" as it plays an important role in avoiding workplace accidents. Recent studies have focused on measuring, sustaining, and improving safety culture in construction organizations (Deepak & Mahesh, 2021; Machfudiyanto et al., 2017). Assessing safety culture is reflected as a proactive method of safety performance (Haslam et al., 2016). Hence, most construction projects aim to minimize injuries and strive to achieve zero incidents, which can only be reached by achieving positive safety culture (Choudhry et al., 2007). Also, frequency of occurrence and severity of the nature of most accidents at construction sites makes it imperative to understand safety culture in the industry.

The sheer number of articles present on a particular research area usually makes it difficult for academicians and practitioners to get a general overview of the specific information. This can quantitatively be analyzed based on information pertaining to publication history, features, and progress of scientific outcomes within a particular research area (Li & Hale, 2016). Moreover, there are several studies related to safety culture research relevant to construction sector, thus making it difficult to have a consistent and thorough overview in this area. The term "safety culture" is possibly the most cited cause for accidents occurring worldwide (Gadd & Collins, 2002; Tetzlaff et al., 2021) and has not been clearly defined in research studies. Moreover, academicians and practitioners have defined safety culture in different domains; thus causing confusion over the definitions and constituents (factors) of safety culture. The scope of any application of safety culture in industrial and practical environment would vary depending on the definition and its constituents (factors) (Swuste et al., 2016). The appropriate definition adopted would influence how people think about the measures and initiatives needed to improve safety culture.

Nearly one-third of studies that propose safety culture definitions do not explicitly discuss the constituents of safety culture. Multiple factors of safety culture are detailed in those studies that discuss them, however, there is no consensus, and different factors are highlighted as the most important. In this regard, the perspective utilized to conceptualize and describe safety culture has an impact on how safety culture can be measured and understood, and this should be a key factor to consider when selecting an appropriate safety culture definition and its constituents. However, there exists diversity in addressing safety culture of construction industry in terms of its definition, factors, and assessment tools that influence the level of safety culture practices. This is because the term "safety culture" is used to describe the elements that influence employee adherence to safety laws and protocols of the organization (Chen et al., 2021; Newaz et al., 2018). Also, the concept has gained acceptance as a vital part of safety management over the last three decades. Researchers and practitioners from various industries and countries have collaborated to establish safety culture in practice (Swuste et al., 2016). Across multiple domains, safety culture research has followed a similar pattern of interest in the notion from industry or

regulators, followed by a collaboration between industry and researchers to develop industry-specific assessment tools.

In this regard, the suitable method for recognizing, choosing, and assessing all literature upon an established level of measurable quality that is suitable to a research problem is conducting a systematic literature review (Booth et al., 2016). This type of review focuses on the process of collecting and gathering all published facts over a topic (Lee et al., 2019). This type of review method helps to summarize available research findings in a more balanced and consistent manner in terms of transparency and objective specificity. However, to the best of our knowledge, no comprehensive and systematic review of safety culture has been published in the area of construction sector which justifies our study. The remainder of this research study is structured as follows: Sect. 2 presents the importance of safety culture in organizations while Sect. 3 describes the research method; Sect. 4 provides the analysis and results; and Sect. 5 presents the conclusion.

2 Importance of Safety Culture in Organizations

Major accidents over the years have made national headlines (e.g., Space shuttle programs like Challenger and Columbia in 1986 and 2003 respectively, epic disaster at Chernobyl in April 1986, Deepwater Horizon oil spill in April 2010, Boeing 737 MAX accident in October 2018), rising concern over health and human error in our daily lives. Much has been learned in following the tragedies, which unveil potential dangers that are embedded in work systems. We have learned that these accidents are most often caused by a set of failures, defective processes, and poor organizational conditions (Khalid et al., 2021; Perrow, 2011). One of the primary underlying causes of these accidents can be attributed to flaws in the organization's safety culture. However, if a good safety culture exists within an organization, the likelihood of events occurring and the effects of those events could be mitigated. Cooper et al. (2019) stated that focusing on these critical safety issues while conducting safety culture evaluations will result in substantially better relationship with actual safety performance. Moreover, many academicians have identified techniques to reduce accident rates, define safety metrics, and develop models to assess safety-related concepts that direct the organization's employees (Al-Bayati, 2021; Vogus et al., 2010; Zohar, 2010).

Investigations of major industrial accidents have related causal factors to 'poor' workplace safety culture (Moreira et al., 2021). An organization's culture is analogous to an individual's identity; which defines his/her values and beliefs and directs his/her behavior. In general, safety culture of an organization focuses on the core assumption that endorses the importance and goals of safety. Reason (1997) points out that safety culture has an important role in any workplace accident. Poor safety culture in the workplace mainly creates an atmosphere in which mistakes are made

more often and violations are generally accepted. This in effect shows vulnerabilities caused by latent and active system failures. In addition, this could be characterized by the inability of the management to identify or resolve weaknesses in its safety management practices. Consequently, these vulnerabilities persist and probably aggravate over a period of time. This increases the risk of impending adverse events which could lead to injury or fatality. Based on this view, the conceptualization of "ideal" safety culture is defined as: "the engine that drives the system towards the goal of maintaining maximum resistance to its operational hazards" (Reason, 1997, p. 294). In practice, this means that safety culture in the workplace has a high predictive value for preventative actions (Aburumman et al., 2019).

Further, a study conducted by Schwatka et al. (2016) indicated some of the predominant issues addressing safety culture in construction sector are: (i) transient nature of the industry, (ii) subcontracting of work, (iii) work organization, and (iv) induction/acculturation process. These issues shape the conception of safety culture as quite complex; challenging content-wise, multi-dimensional, and a cross-disciplinary study area (van Nunen et al., 2017). Also, in addressing these adverse issues, organizations need to encourage safety culture practices for creating a positive working environment within the organization (Wang et al., 2020). Dealing with issues of safety culture research is relatively new phenomenon related to academic research. The conception of safety culture began in reaction to Chernobyl disaster which occurred in 1986, and with time, there is rapid increase in studies on safety culture. However, accidents and incidents still remain a concern in this sector (Luo et al., 2022). The notion of improving safety culture at the workplace is believed to act as an accident prevention system (Gabryelewicz et al., 2015; Khalid et al., 2021). Furthermore, a study conducted by van Nunen et al. (2017) highlights the development of safety culture model in relation to construction sector; yet, there is no consensus regarding the definition, factors, and cause and consequences of the same. Many theories have been formulated to link safety performance and its relationship with safety culture of the organization (Gadd & Collins, 2002; Guldenmund, 2000). Moreover, this has led to constant growth in number of articles on this topic, thus making it challenging to attain a detailed overview of this topic. In an effort to address this issue, a systematic literature review is undertaken to define and broaden the current knowledge and understanding on the topic of safety culture in construction sector. This type of review differs from traditional narrative reviews as it is reproducible, logical, and more transparent (Newaz et al., 2018); in other words, it is a comprehensive methodology aimed at reducing bias obtained through exhaustive literature reviews of reported studies and provides an audit trail of judgments, procedures, and conclusions of the reviewers (Qureshi et al., 2020).

The relevance of this study is that, while certain safety initiatives have been successful, there is a lot of inconsistency in the relationship between safety culture and its consequences. This indicates that there is a need to examine and develop our understanding of safety culture and its influence in the construction sector.

3 Research Method

The research approach adopted in this study consists of comprehensive review of safety culture articles and is undertaken using a 3-step methodology. First step intends to collect recent safety culture articles. Then, these articles are codified based on selection criteria that are related to safety culture aspects of construction sector. In the second step, these codified articles are analyzed by descriptive analysis to highlight recent trends in safety culture research. Last step focuses on conducting a systematic review to have a comprehensive overview of safety culture studies. Detailed methodology map adopted in this study is presented in Fig. 1.

3.1 Literature Search

Safety culture articles were collected from web-based search conducted on the SCOPUS database. This database search conducted using SCOPUS offers consistent and accurate results and covers wide range of discipline-related publications and assists with keyword searches and citation analysis (Chellappa et al., 2021; Newaz et al., 2018). Literature search was made on keywords search for the keyword 'safety', 'safety culture', and 'construction'. The keywords search for these terms were made on 'title', 'abstract', and 'keywords' of articles that are published in various journals from 2000–2021. This search yielded 140 articles and the data of these articles were exported to Microsoft Excel version 2013.

3.2 Keyword Co-occurrence Analysis

In this analysis, the number of co-occurrence of keywords in the search criteria of articles is mapped that can offer insight into key topics and trends of a particular interest area (Goerlandt et al., 2021; Li et al., 2021). The articles that were obtained from literature-search method were used to analyze the keywords. This analysis is carried out as searching within the SCOPUS database offers several possible research articles at disposal (Jin et al., 2019). In order to identify whether the intended search truly reflects the criteria, the co-occurrence of keywords from the articles was analyzed. VOSviewer version 1.6.5 was used to examine and visualize the keywords (Van Eck & Waltman, 2010; Zeng et al., 2022). VOSviewer is a freely available tool (www.vosviewer.com) that allows users to analyze bibliographic records that are directly imported from SCOPUS database used for visualizing networks and patterns (Chen et al., 2021; Li et al., 2021).

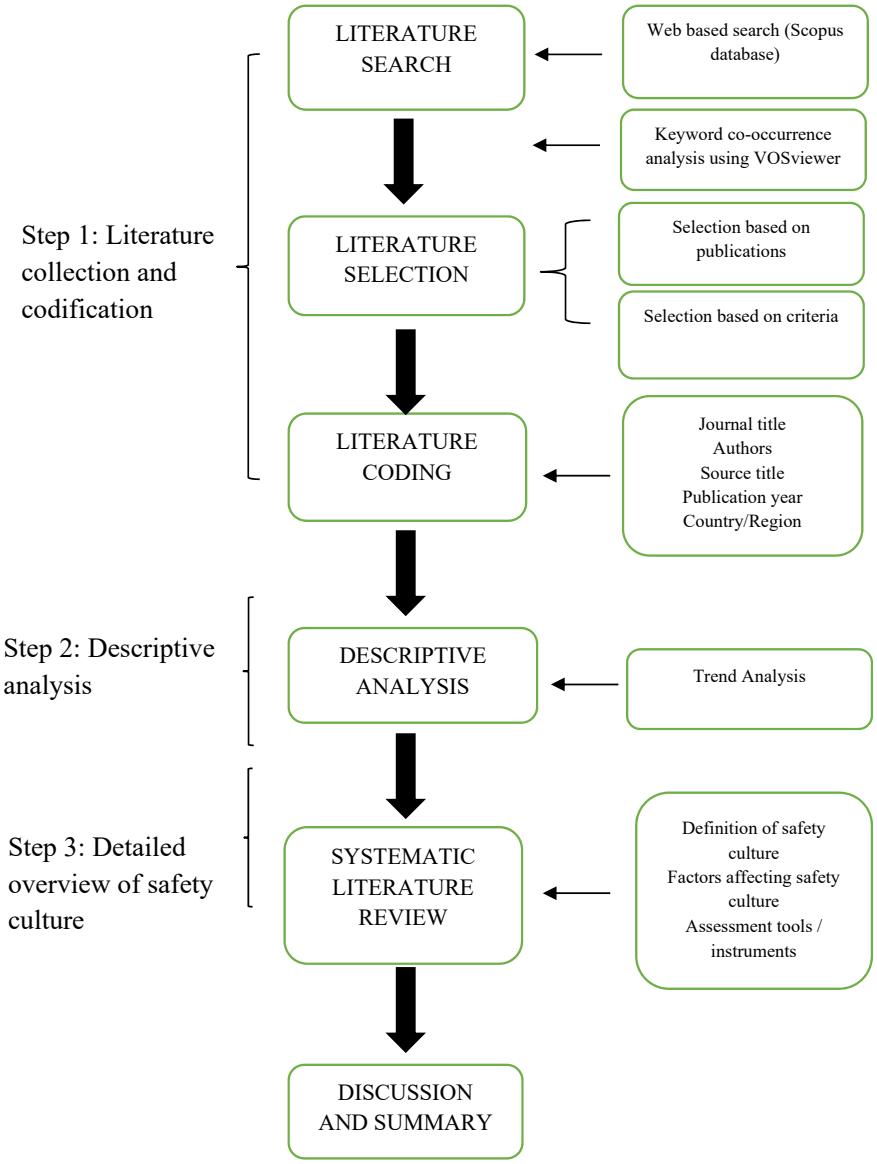

Fig. 1 Methodology map

3.3 Literature Selection

The obtained articles were further scrutinized based on certain criteria of the study since the objective of the review is not focused on gathering sufficient articles, but to provide insight on current trends on the topic. Also, exclusions were made even

though they match the subject on safety culture. Exclusion criteria include; (i) No direct relevance of the search keywords to safety culture in construction sector. Keyword 'construction' in many cases does not refer to construction sector but is used as a 'construct' of an event in general. (ii) Only the words matching the criteria were considered for the study. As a result, 51 relevant articles were obtained after exclusions.

3.4 Literature Coding

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

3.5 Systematic Literature Review

The last step of the proposed 3-step methodology is to conduct a systematic review to have a comprehensive overview of safety culture studies. While this systematic literature review limits its focus on construction sector, some of the essential papers that focus on safety culture studies were included because of limited theoretical studies being done on construction sector. These studies serve as a new perspective for exploring the commonalities among multiple industries that can be applied to construction sector. Traditional literature review limits its focus on proper identification of research area and knowledge structure. Together, these are considered subjective as they are generally determined by the author's decision. In this regard, a structured systematic literature review addresses these aforementioned issues and outlines the conception of safety culture in organizations. This majorly covers an overview of defining safety culture in organizations, conceptualizing various safety culture factors that define these concepts, and lastly, assessment tools for measuring the level of safety culture in organizations.

4 Analysis and Results

4.1 Keyword Co-occurrence Analysis of Safety Culture Research Areas

Results of keyword co-occurrence analysis offer key insight into important topics and trends of safety culture research domain. This mapping of interrelated keywords gives an accurate representation of empirical knowledge development with respect to themes, linkages, and cognitive structure of the topic of interest (Bautista-Bernal et al., 2021; Jin et al., 2019). Results of keyword co-occurrence analysis network are shown in Fig. 2. From the analysis, the magnitude of the circles denotes the occurrence of a term (Goerlandt et al., 2021). The distance between the terms offers information about their relationship. This relationship of the terms is signified based on the occurrence of the terms (Li et al., 2021). Different colors distinguish one another from belonging to different groups. Most common keywords obtained are; safety culture, accident prevention, human, safety, safety climate, safety performance, surveys, occupational safety, safety engineering, and construction safety.

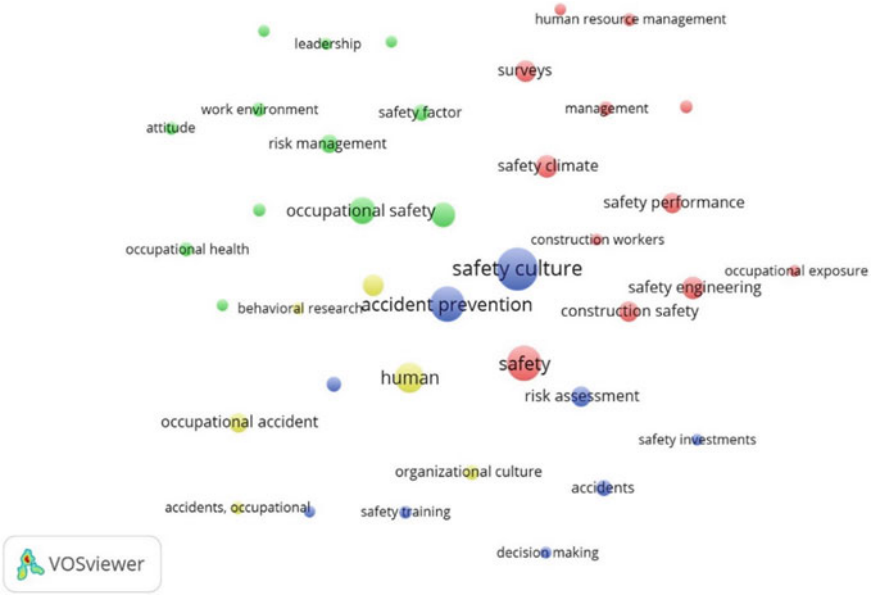

Fig. 2 Keyword co-occurrence analysis network of safety culture articles (2000–2021). *Source* www.vosviewer.com

4.2 Descriptive Analysis of Safety Culture Research

Descriptive analysis is conducted to get a broad picture of the current status of safety culture studies in construction sector. Results that are attained from the data of codified articles are presented in this section. Recent trends in this area are analyzed by presenting the distribution of safety culture articles based on; (i) journal, (ii) year of publication, and (iii) country/region-specific.

The amount of scientific articles published in a specific research area can be considered as an essential indicator to quantify its recent trends (van Nunen et al., 2017). These 106 articles obtained are analyzed based on the type of journal. Figure 3a provides information on most journal articles on safety culture topics. Key journals in the field are 'Safety Science (SS)', 'Journal of Construction Engineering and Management (ASCE)', 'Journal of Management in Engineering (JME)', 'Advances in Intelligent Systems and Computing (AISC)' and 'International Journal of Occupational Safety and Ergonomics (JOSE)'. The number of safety culture articles showed an uptrend from 2006 and 2017 as indicated in Fig. 3b. Then, there is a constant increase in the growth rate of articles except in 2010, 2011, and 2014. Highest number of articles have been published in 2019 (n = 16) and 2021 (n = 16); with declining trend in 2014 (n = 1) and 2016 (n = 4). However, the development maturity point has already been reached in this particular area or field with lack of consensus on its features and concept of safety culture in construction sector.

Careful examination of cumulative number of articles over the years indicated that the importance of the topic has increased tremendously (Fig. 3c) and has become an

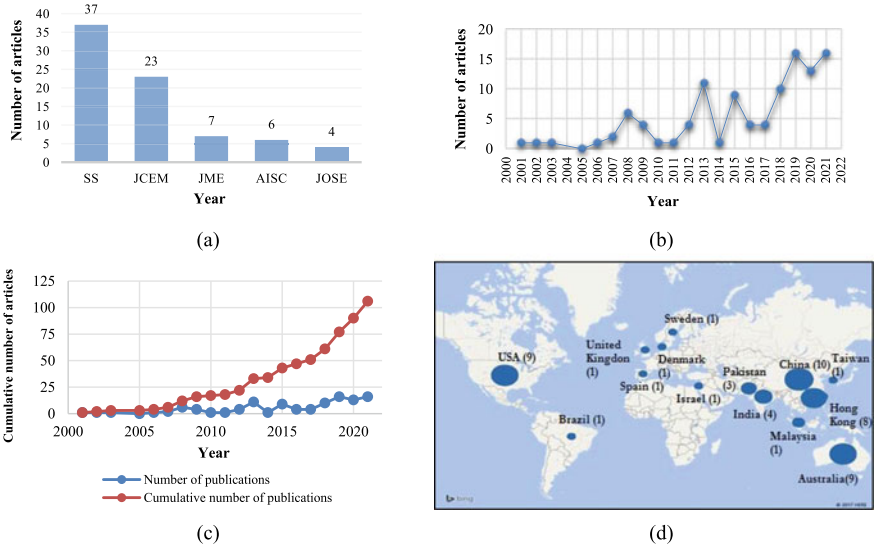

Fig. 3 Descriptive analysis of safety culture articles

important part of construction management research. This increased pattern can be compared with other safety-related articles as demonstrated in Li and Hale (2016).

Safety culture articles related to construction sector were majorly from 16 different countries or regions and the worldwide distribution of the contributing countries or regions is shown in Fig. 3d. China has contributed with most articles (n = 10), then by USA and Australia (n = 9), Hong Kong (n = 8) and India (n = 4). In these countries, there has been an increase in articles due to pressing concerns towards safety management in construction sector.

4.3 Systematic Literature Review on Safety Culture Studies

Primary focus of conducting this review is to ensure a complete overview of safety culture studies. The systematic literature review methodology outlines the conceptualization of safety culture and at first, provides an overview by defining in construction sector-specific. Then, various factors that define the concept of safety culture are examined. Lastly, the assessment tools for measuring the level of safety culture are highlighted.

4.3.1 Defining Safety Culture in Organizations

The term safety culture was recognized soon after the Chernobyl accident (IAEA, 1986). However, no exact explanation of the term was provided for two main reasons: (i) several researchers highlight numerous safety culture elements as most significant, and (ii) culture of any kind is a tough thought to compactly outline. Some of the commonly used definitions that are believed to capture the essence of safety culture have been listed in Table 1.

The first scientific conceptualization of the term safety culture was proposed by Zohar (1980), and this empirical study was developed based on a survey conducted amongst Israeli production workers. This study is recognized as a seminal study that has established the current direction for research as much of the work on this topic focuses on a pragmatic approach rather than conceptual or theoretical issues of safety culture. Further improvements on defining the concept were made and these are summarized in Table 1. Most definitions mentioned in Table 1 are analogous in their beliefs and perceptions with each of them focused on varying degrees in relation to safety. Even though the definitions differ from one another, yet there is common agreement that safety culture is being regarded as a proactive approach concerning safety management.

Definitions mentioned in Table 1 are extracted from various disciplines (human psychology, healthcare sector, manufacturing sector, construction sector, etc.). The observable degree of effort put forth by all employees to increase safety knowledge and actions in the workplace is referred to as safety culture (Cooper, 2000). This

Table 1 Safety culture definitions

Author and article	Definitions
Guldenmund (2000)	"Aspects of the organizational culture that will impact on attitudes and behaviour related to increasing or decreasing risk"
Cooper (2000)	"Observable degree of effort by which all organizational members direct their attention and actions toward improving safety on a daily basis"
Mohamed (2003)	"A sub facet of organizational culture that affects workers' attitudes and behaviour in relation to an organization's on-going safety performance"
Fang and Wu (2013)	"A mixture of attitudes, beliefs, values, behaviours, and norms held by the individuals and groups from different parties in a construction project team, and it is gradually formed and evolved in the construction project environment that would influence the commitment to, and the style and proficiency of how all parties involved in the project and its personnel act and react in terms of the ongoing safety performance"
Al-Bayati and Panzer (2019)	"The principles and policies of a construction firm that guide safety decision-making at the firm management level"
Trinh and Feng (2020)	"A culture that can be created in a construction organization by systematically responding to the potential threats against which resilience protects: project hazards (regular threats), human errors (irregular threats), and unexpected failures (unexampled events) in the construction environment"
Bhagwat and Delhi (2021)	"The management personnel (top and middle management) perceive the existence of safety culture through compliance with safety practices and compare and contrast it to the workers' perception of the adequacy of such compliance"

would in turn affect an individual's perception, attitude, and behavior in the organization (Sudiarno & Sudarni, 2020). These measurable attributes are indicated as safety climate. Hence, safety climate is considered to be the reflective state of the organization's safety culture. Moreover, the concept of defining safety culture in construction sector truly reflects the concept explained in other disciplines. Among these, the definition provided by Fang and Wu (2013), has attempted defining safety culture at construction project level. This seems to be more practical, as it clearly outlines the concept of safety culture relevant to construction sector. Further, this indicated that the definition of safety culture is clear and clarified in the context of construction sector.

4.3.2 Factors Affecting Safety Culture in Organizations

Keyword co-occurrence analysis as explained in the earlier section only shows the most occurring terms in a given text. But, a detailed analysis of terms is considered necessary for safety culture research that truly reflects the concept; which ultimately

results in identifying the factors that affect safety culture. In this regard, the focus is on identifying the key factors considered among various sectors. These factors signify a clear association existing among safety culture concepts and highlight the fundamental areas of safety management research. But it is challenging to comprehend the underlying interactions existing between the antecedents and consequences of safety culture research, as these influencing factors are not consistent but are fragmented. Also, there exists little agreement on safety culture factors that suggests multiple features and complexity of safety culture concept.

Most safety culture models mainly address three dimensions to define the concept (i.e., personal, behavioural, and situational) (Ismail et al., 2021). Various factors that affect safety culture are categorized under these dimensions. Detailed descriptions of safety culture dimensions with influencing factors are mentioned below:

i. Personal factors: This comprises of psychological aspects in terms of perceptions, attitudes, competencies, and values of individuals and groups towards safety and describes "how people feel within an organization safety management system?" and is evaluated through safety questionnaires. Factors under this dimension include; co-worker's commitment and involvement to safety, worker competence, and control, safety attitudes, trust among employees, subcontractor involvement, and safety incentives and disincentives (Liao et al., 2014; Mohammadi et al., 2020; Pandit et al., 2020; Zhou et al., 2015).
ii. Behavioural factors: This deals with actual ongoing safety-related actions and behaviours and describes "what people do within an organization safety management system?" and is evaluated through safety checklists. Factors under this dimension include; supervisor commitment to safety, risk management, safe work conduct, and workplace safety practices (Chen et al., 2013; Mohammadi et al., 2020).
iii. Situational factors: This encompasses situational features that include policies, procedures, regulations, organization structure, and the management system. It describes "what the organization has or has to put in place?" and is evaluated through safety audits and inspections. Factors under this dimension include; safety policies, resources and training, management commitment, safety communication, and top management safety response (Fang & Wu, 2013; Han et al., 2014; Mohammadi et al., 2020).

The categorization scheme for grouping each of the factors under safety culture dimensions is based on the author's consideration of these factors in their safety culture studies. These factors greatly influence the level of safety culture in any organization. Hence, more focus has to be given to these influencing factors for achieving positive safety culture in the workplace.

4.3.3 Assessment Tools for Measuring Safety Culture in Organizations

Numerous definitions of safety culture have caused lack of consensus to include factors required to develop safety culture measures. Nonetheless, while the literature

on the subject has progressed conceptually, it is still in its early stage in terms of the development of quantitative instruments for measuring and evaluating safety culture at the workplace, which reinforces the necessity of addressing the idea; as well as a holistic strategy that takes into account technology, organizational, and human factors (Olugboyega & Windapo, 2019; van Nunen et al., 2017). As discussed in the previous section, there exist several factors affecting safety culture that is considered in different sectors. Proper identification of measuring instruments is essential to assess safety culture in respective organizations. In real-time applications, one needs an effective assessment tool to measure the level of safety culture; and, in this regard, five most prominent tools in different sectors with their features and limitations are enumerated in Table 2. These assessment tools obtained from different sectors typically consider quantitative questionnaires which are based upon any number and combination of the factors mentioned in the earlier section. Among these tools, Safety Climate Assessment Tool (S-CAT) is an assessment tool that is holistic in nature and is specifically designed for construction sector (Probst et al., 2019). This tool is developed based on recommendations and inputs provided from multiple stakeholders concerned in construction projects and this practical tool can be utilized by contractors to improve safety culture at their job sites. The existence of variety in safety culture measures acts as a key indicator of how safety research is quickly developing as a meaningful assessment tool in construction sites.

When choosing a safety culture instrument for examining the level of safety culture, one has to consider its applicability to specific industry and whether all the factors are within its scope. These assessment tools are primarily based on conducting perception survey among the employees (Deepak & Mahesh, 2021; Zhou et al., 2015). These surveys aim to capture perceptions of employees in the organizations accounting for safety culture practices (Guldenmund, 2000). Clear and positive understanding of workplace safety elements contributes to the development of positive safety climate and in turn, enhances safety culture. Also, Mohamed (2003) recommended that safety culture deals with factors that have the ability to manage top-down organizational safety; whereas, safety climate deals with the view of front-line workers on the role of bottom-up workplace safety. Survey instrument helps in determining the strong and weak points of safety management practices being adopted in organizations. Assessing safety culture factors is essential to distinguish the level of safety culture in various sectors. Although, some of the ethnographic studies make the measurement approach difficult as they consume time and money. To overcome this, assessment tools are developed to measure the level of safety culture.

5 Conclusions

Despite continuous improvements in safety management studies in construction sector over the years, occupational safety-related issues are still in existence. Many organizations have shown greater attention towards facilitating safety culture as a

Table 2 Safety culture assessment tools

Instrument/tools	Industry	Features/highlights	Drawbacks/Limitations
Score your safety culture checklist (Reason, 2001)	Transport and medical service	• Comprises of 20 statements. It is based on 'yes', 'no', 'I don't know' type answers • Convenient for interpreting the calculation-based result and does not require an expert for using the checklist	• Questions are complex and need necessary modification for applying to different industries
Loughborough University Safety Climate Assessment Toolkit (LSCAT) (HSE, 1999)	Offshore	• Comprises of forty-two statements and adopts triangulation rule for assessment	• Triangulation of results can be difficult for inexperienced professionals
Safety Health of Maintenance Engineering (SHoME) Tool (SHoMe, 2003)	Aviation	• 3 different sets of survey instruments for different management levels; can also be used for varying project sizes	• Not universal and yet specially designed for aviation industry
Nordic Occupational Safety Climate Questionnaire (NOSACQ-50) (Kines et al., 2011)	Production and service sectors	• The survey consists of 50 questions. It is developed in different languages and is universal and can be applied to different management levels and industry sectors	• Involves complex questions and thus results are difficult to interpret
Safety Climate Assessment Tool (S-CAT) (Probst et al., 2019)	Construction industry	• Consists of 8 leading indicators that have been shown to predict employee injury rate • Responses to these indicators are provided with customized feedback report; also give information on success areas and provide suggestions for improvements	Advantages • Holistic approach • Designed specifically for the construction industry

means to decrease accidents, incidents, and risks occurring at the workplace. Safety culture research is important and essential since it is a component of any organization that focuses on increasing the organization's safety. In this regard, the amount of peer-reviewed articles published and the diversity of study topics have been increasing in this area. However, the amount of literature available on this topic makes it challenging for practitioners and researchers to have a structured outline of the topic.

Therefore, a systematic review is undertaken to synthesize existing research articles on evidence-based approaches required for planning and implementing serval interventions to enhance the workplace safety culture in construction sector. This review is considered as a systematic methodology for reviewing the detailed aspects in the existing safety management literature and uncovers significant findings and reveals knowledge gaps for future work. Since systematic literature review adopted in this study limits its focus on construction industry, it thereby facilitates in exploring the concept of safety culture in terms of formulation and advancement towards the body of knowledge. This limitation can be overlooked by conducting a deeper content analysis on articles of safety culture research. Another minor limitation of this study is that the data collected and thorough review of articles is done from international studies; as construction industry of each country has somewhat unique characteristics, which can be taken into account in future research.

While exploring the studies on safety culture, this chapter defined safety culture, identified actionable factors, suggested assessment tools for construction sector, and emphasized that these can assist researchers and practitioners to have consensus on industry-specific standards. Furthermore, this systematic literature review has helped to conceptualize safety culture in construction sector.

This review's main objective is to understand the conception of safety culture in terms of its definition and assessment required to predict and explain health and safety outcomes in construction sector. The information presented here offers a comprehensive image of research progress in the field of safety culture research, and it can help academicians and practitioners identify fundamental influence from these published articles. Also, this provides insights on various constructs of safety culture studies in construction sector till date and makes an effort to identify the recent trends and advances towards creating a safe working environment within construction sector. It is assumed that this review will encourage further studies on safety management aspects in construction sector.

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Developing Safety Capabilities in Integrated Project Delivery: Mobilising the Institutional Analysis and Development Framework

Andrea Yunyan Jia

Abstract This chapter explores the potential of Ostrom's Institutional Analysis and Development (IAD) framework as an actionable theory in guiding safety capability development for Integrated Project Delivery (IPD). It does so through the dynamic formation of action situations that incentivize and nurture the desirable capabilities for collaborative practice. A worked example is presented to illustrate how the IAD framework works for this purpose. Following an in-depth review on IPD and safety literature, which defined a set of safety capabilities for IPD practice, the system designer set up initial IPD-oriented game rules which incentivized actors' experiences that nurture such capabilities. The reflective analysis results highlight three key perspectives in mobilising the IAD framework for safety capabilities development: (1) an organic power division between top-down design and bottom-up development of institutions; (2) an inclusive project front-end that involves actors in problem-framing activities; and (3) capabilities development as a process of shifting logics. Practically, the results inform effective training and coaching of practitioners at the teambuilding stage of IPD projects to configure safety as an integral attribute of the project system. Theoretically, the research contributes to the development of institutional theories in the project management context.

Keywords Integrated Project Delivery (IPD) · Institutional Analysis and Development (IAD) framework · Safety capabilities · Institutional logic

1 Introduction

Integrated Project Delivery (IPD) is a collaborative arrangement in the delivery and management of construction projects which involves multiparty contract, risk/profit sharing and integrated teamwork (Lahdenperä, 2012). The institutionalisation of IPD offers a promising prospect to end the long-standing fragmentation in the industry through a 'disruptive systemic innovation' (Levitt, 2007; Hall, 2018). Safety, as a key

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theme of construction project delivery, is having an opportunity to be horizontally integrated into the process and the product of an IPD project, thus expecting a substantial improvement along with the diffusion of IPD. A key challenge to this transition process is the shortage of capabilities for collaborative practice, as existing practitioners' capabilities are deeply embedded in their experiences with the traditional procurement system.

From an institutional perspective, a project organising process is to bring a situation of ambiguity and uncertainty into full order and certainty (Winch, 2001; Levitt & Scott, 2017). Parellel to the technical work is an institutional development process where actors develop new routines of collaborative practice in each unique project context (Biesenthal et al., 2018; Gil et al., 2020), the experience of which generates capabilities for managing the new situation (Zerjav et al., 2018). Thus, an important path to build up the new capabilities is to make ongoing IPD projects vehicles of change and development through team selection (Towner et al., 2015; Franz et al., 2017) and mindful governance (Söderlund & Sydow, 2019) to create a cause and an institutional environment that motivate collaborative behaviour.

For systematic planning and management of this process, an institutional theory is needed to provide a lens and a guide. Many institutional theories can explain project practice but few are actionable for guiding emergent practice (Argyris, 2003). One exception is Elinor Ostrom and colleagues' Institutional Analysis and Development (IAD) framework (Ostrom, 2005), a metatheory that interprets actions in their situations defined by the attributes of the resources and the community of actors and the rules-in-use. Recent research on construction projects has attempted to use it in analysing IPD project governance (Hall, 2017), policentricity of megaproject organisations (Gil & Pinto, 2018) and multiple logics of managing safety in megaprojects (Jia et al., 2019). These precedents open a pathway for further application of the IAD framework in guiding IPD practice (Brady & Davies, 2004; Fischer et al., 2017). Built on the existing work, this study mobilizes the IAD framework to guide the dynamic formation of action situations in the project process that foster IPD-enabling safety capabilities. Through a worked example, the study shed light on how it works and how to make it work in a construction project context.

2 IPD and the Challenge of Capability Shortage in the Industry

IPD is a collaborative project procurement arrangement defined by a specific project governance structure (IPDA, 2016), a business model (Ashcraft, 2014), a broader philosophy on relational contracting (Lahdenperä, 2012). As a specific project governance structure, an IPD project involves key elements including early and continuous involvement of key players (and particularly the client), team colocation, shared risks and profits, joint project control, single multiparty or inter-locked agreement

and liability waivers (AIA, 2007, 2014; Mesa et al., 2016). The contractual arrangements are formal institutions providing a structure for actors of conflicting interests and incompatible institutional logics to work coherently to achieve higher efficiency (Baiden et al., 2006; Lahdenperä, 2012). As a business model, the profit of an IPD project comes from effective teamwork, in contrast to a traditional project which expects a significant amount of profit coming from claims and disputes among the project stakeholders.

However, contract-specified structures do not necessarily bring about integration (Cicmil & Marshall, 2005; Suprapto et al., 2016). For example, rework and fragmentation can still prevail in alliance projects: '*Design wasn't talking to construction, construction hated design, and project managers felt that everyone else wasn't pulling their weight*.' (Love et al., 2015: 4). In practice, IPD projects have more or less elements embedded in the traditional delivery approach (c.f. case studies by Bygalle et al., 2015). On this, Walker and Lloyd-Walker (2016a) provide a relationship-based procurement taxonomy for organisations of diverse capabilities profiles to craft bespoke collaborative delivery models (Walker & Lloyd-Walker, 2016b: 4). Thus, IPD might be more broadly defined as a general concept of relational contracting manifested in various levels and forms of integration, including IPD, alliancing, competitive dialogue, design-build, partnering, etc. (Walker et al., 2017). In the very essence is a logic of collaborative practice and integrated system, the enactment of which takes project and individual capabilities (Fischer et al., 2017; Clegg et al., 2018).

Existing capability profiles of actors in the industry are deeply embedded in practitioners' experience with the traditional system and its adversarial culture (Rowlinson, 2017). For example, Ebrahimi and Dowlatabadi's (2018) found major challenges on IPD practice as: (1) lack of consensus among the 'traditional adversarial mentality' of IPD practitioners that leads to fruitless meetings; (2) project managers unprepared for the intensified time and resource at the project front-end; (3) actors' permanent organisations remain operating in the risk-aversion way, which constantly disintegrates the IPD team during the in-and-out; (4) consultants' reluctance to join multiparty agreements due to lack of skills and knowledge in handling the close partnership, uncertainty and new liabilities; (5) inadequate capabilities in innovation, communication, inter-personal skills, personal leadership; (6) team members' personality un/fit; (7) scarcity of experienced individuals; (8) training and coaching on IPD teamwork overlooked or cut short, giving way to progress pressure. A key underlying issue of these challenges is a shortage of capabilities in the industry for effectively undertaking of integrated practice.

3 The Experiential Learning Approach to Capability Development

Capabilities are knowledge, abilities and values that can be mobilised to comprehend and solve the problems in real world situations (Argyris & Schön, 1974; Davies & Hobday, 2005). Espoused values are not capabilities unless they are materialised in

actions. That is, unless the lessons learned are enacted by new practices, learning has not happened in a real sense (Atkinson et al., 2006: 696). Capabilities that enable collaboration include abilities of communication and coordination (Tee et al., 2019), inter-professional leadership and interpersonal skills (Fischer et al., 2017), systems integration and learning (Brady & Davies, 2004; Walker & Lloyd-Walker, 2016b). These capabilities are needed in the traditional system, too, but are of a different nature under the IPD system due to its intensified concurrency and collocation.

Davies et al. (2009) illustrate a path how Lang O'Rouke developed IPD capabilities through the experience of working with the client the British Airports Authority (BAA) on the Heathrow T5 project. From this experience the firm acquired key personnel for integration management, which enabled it to take up the system integrator's role in the Crossrail project (Davies et al., 2014). This process suggests that capabilities are developed through experience of performing a specific role in the delivery of a project while navigating through a specific institutional context (Winch & Leiringer, 2016). Davies and Brady (2016: 316) define capabilities as '*previously learned patterns of action embodied in regular, predictable and respective routines*'. This is operable at both individual and organisational levels.

Experiential learning theories (Argyris & Schön, 1974; Kolb, 1984) suggest that capabilities are developed through the experience of engaging with a reflective dialogue with uncertain and ambiguous situations to develop integrated solutions that address varied constraints. Schön (1987) exemplifies the project-based learning-by-doing in architectural design studio as an effective approach to developing professional competencies. The learning journey starts from a real-world situation and a broad specification of the design task; a novice is expected to gain capabilities through sensemaking, problem-framing, prototyping and testing out solutions in addressing the initial situation (Schön, 1984). Authentic professional knowledge is generated 'in' the engagement of these actions (Crawford et al., 2006). In this process, a novice plays equal with an expert to be held accountable for his/her decisions (Chan, 2016), while the educator's job is to create a cause (a project to deliver) and an institutional environment that motivate the novice to acquire needed capabilities in thriving to accomplish the task (Boland & Collopy, 2004).

4 Safety and IPD

In the fragmented industry context of the construction sector, safety management has particularly suffered from the invisible walls vertically between key stakeholders, horizontally between organisations and professions, and temporally between different stages in a project lifecycle (Egan, 1998; Fellows & Liu, 2012; Hall et al., 2014, 2020; Oswald et al., 2020). In lateral fragmentation, safety is educated as a separate discipline and practiced as 'another' profession in construction, somewhat alienated from the business of the project (Jia et al., 2017; Lingard et al., 2019). Multiple organisational interfaces in a construction project lead to inefficiency and ineffectiveness in risk communicaion and mitigation (Lingard et al., 2011). For example, the

author in her ethnographic fieldwork in a megaproject observed that a manager came across a subcontractor's worker engaging with some unsafe behaviours, only to find himself unable to intervene, because "they are not our workers". His intervention on the worker's unsafe behaviour would have to go through inter-organizational communication via the worker's manager. In vertical and temporal fragmentations, people, knowledge and information are segregated by project phases, such that risk mitigation is often lost in communications across the supply chain or organisational hierarchies. In this respect, Walker and Lloyd-Walker (2016a, 2016b) suggest integrated team effort is needed for effective control of safety risks.

In the awareness of the fragmentation issues, policy-makers and projects have made efforts to bring site safety concerns to the project front-end through initiatives such as safety-in-design (Gambatese et al., 2005; Hare & Cameron, 2012; Lingard et al., 2014b; HSE, 2015; Wuni et al., 2021), client-driven safety-oriented system reengineering (OFSC, 2008; Lingard et al., 2009), early contractor and supplier involvement (Lingard et al., 2014a; Saunders et al., 2015) and off-site construction (Blismas & Wakefield, 2009). Notwithstanding, vertical integration results in reorganisation of the supply chain, which changes patterns of on-site work activities and therefore patterns of risks and accidents on site (Arashpour et al., 2016; Wuni et al., 2021). These changes challenge the project team for new capabilities in systems thinking, integrated teamwork, resilience, mindfulness and dynamic risk mitigation.

In concert with practice, recent theoretical models of construction accident causalities developed from field data have a growing focus on systemic embeddedness of safety factors (c.f. Haslam et al., 2005 and Gibb et al., 2006 model developed from 100 non-fatal accidents; Hale et al., 2012 model developed from 26 fatal accidents; Rowlinson & Jia, 2015 model developed from 36 heat-related incidents). Seeing major projects as fields of conflicting logics (Biesenthal et al., 2018), Jia et al. (2017, 2019) define three institutional logics of safety practice in construction projects: a protection logic, a production logic and a reconciling logic. The protection logic assumes safety and work are mutually exclusive and their management an either-or choice; the production logic assumes safety as an extra task externalised to the business of the project; and the reconciling logic assumes safety as an integral attribute of the production system. The production logic predominates safety practice in the developed countries and subsequently, the assumption of safety as an extra work package of the project underlines the body of safety knowledge. The reconciling logic that assumes integration between safety and production is found in the bottom-up work-community-led initiatives (Jia et al., 2017), in innovations that improve both safety and productivity of the project (Kumaraswamy et al., 2004), and in integration management (PMI, 2017).

Based on a reconciling logic, safety management can be more broadly defined as *the preservation of human lives, including quality of life* (Jia et al., 2020). This definition takes safety, health, wellbeing and fulfilment under a single care, and safety management as an integral attribute of the human resource management system of the project organisation. On this basis, drawing further from systems thinking (Rasmussen, 1983; Dekker, 2006, 2011; Hollnagel et al., 2006; Leveson, 2016 [2012]; Goh, 2018), a set of IPD-embedded safety capabilities are identified in Table 1.

Table 1 IPD-embedded safety capabilities

Capabilities	Explanation
People first	Recognise productivity comes from a healthy and self-motivated workforce (in contrast to the exploitation approach) (Levitt and Samelson, 1993; Loosemore et al., 2003; Oxenburgh et al., 2004)
Caring	Attend to team member's diverse characteristics; understand and accommodate their strengths, needs and difficulties (in contrast to the task-centred, command-and-control approach) (Lingard & Francis, 2009; Hale et al., 2010)
Problem-framing	Be able to comprehend a situation of ambiguity and uncertainty, and frame the problems that point to effective solutions (Kvan and Gao, 2004; Snowden & Boone, 2007; Walker et al., 2017)
Engagement	Involve, consult and develop employees (instead of hire-and-fire) (Westrum, 1993; Lawani et al., 2017)
Inclusiveness	Embrace differences and diversity; motivate team members to participate (Lowe, 2010; Zwetsloot et al., 2013)
Mindfulness	Stay authentic to the meaning of the work (Weick et al., 1999)
No-blame	See mistakes as learning opportunities; seek to solve problem rather than lay blames (Dekker, 2006; Love & Smith, 2016; Walker et al., 2017)
Forgiveness	Capability of absorbing the consequences of teammates' mistakes; go an extra mile to complement; keep the system working despite others' errors or dysfunction (Strang, 2001; Senge, 2006; Caldwell & Dixon, 2010)
Resilience	Be responsive to emergent issues (in contrast to non-reflexive practice); respond resiliently to interruptions to keep the system functioning (Senge, 2006; Winwood et al., 2013; Turner et al., 2016)
Integration	Integrate safety values in production goals of the project; address complexity, join fragmented parts into a coherent whole (Brady & Davies, 2014; Griffin, et al., 2014; Lobo & Whyte, 2017)
Innovation	Reconcile dilemmas and contradictions through creative solutions (Hoven, 2013; Lobo & Whyte, 2017)
Systems thinking	Address interdependency and interconnectivity; understand the dilemmas in making safety-related decisions in projects; identify causalities of accidents in systemic context; locate self-responsibility and substantiate what "I" can do about it (Senge, 2006; Dekker, 2011; Rowlinson & Jia, 2015; Goh, 2020)
Learning	Reflective practice; learning-in-action (Jia, 2009; Walker & Lloyd-Walker, 2016b; Abankwa et al., 2021)

5 The IAD Framework

The Institutional Analysis Development (IAD) framework is a meta-theory for understanding how institutions shape practices across sectors, levels and domains (Kiser & Ostrom, 1982; Ostrom, 1986, 2005, 2011; Ostrom et al., 1994). Institutions are defined as 'rules of the game' (North, 1990) or 'regularities of human behaviour' (Ostrom, 1990). To the new institutional economists, the effort of fitting institutions with social context is driven by a motive of minimising transaction cost (Coase, 1937;

Williamson, 1975). However, Winch (1989) observed that players in the construction sector preferred a higher transaction cost approach (i.e., fragmentation) despite its inefficiency. Insights from the neo-institutionalism sociologists (Powell & DiMaggio, 1991; Brinton & Nee, 1998; Fine & Milonakis, 2009) suggest that the normative and cultural-cognitive institutions (Scott, 2008; Scott et al., 2011) can have a direct effect on behaviours in, on and of a project, not necessarily through an economic logic.

In the case of IPD practice, the IAD framework is potentially a useful guidance for the formation of action situations that incentivise collaboration and teamwork. Hall (2017) applied its principles in his analysis of IPD project governance, drawing on its process as a common-pool resource scenario. Gil and Pinto (2018) draw from it to analyse the polycentric nature of megaprojects. Essentially, project as a temporary organisation involves a bottom-up institutional development process, for, as Fischer et al., (2017: 192) have argued, smooth teamwork among the cross-functional stakeholders and professions is 'largely self-managing and self-coordinating'. The IAD framework provides a bottom-up perspective on how an institutionalisation process can occur organically through local actors' self-organising practice of crafting rules to manage common pool resources. It provides a set of key variables from which more specific theories can be tailored or fitted for use. At the centre of the IAD framework is an 'action situation', which explains how institutional context impacts on actors' actions at operational, organisational and constitutional levels (Ostrom, 2005). The action situation is shaped by the attribute of the technical task (the resources to be set into order), the actors' community and the constructed rules-in-use.

Ostrom (2011) classifies rules-in-use into seven types according to their influence on an action situation. *Boundary rules* deal with the pool of legitimate actors involved in the project (their attributes, resources, condition of entry and exit). *Position rules* address actors' role and responsibilities. *Choice rules* address choices of actions that actor of a position must, must not or may have; and mandatory, authorised or forbidden technologies for production and monitoring. *Authority rules (or aggregation rules)* concern with decision-making procedures and discretions that enable an action to take place. *Information rules* define who can communicate what through what channel, channels of authorisation, and legitimate information flows. *Payoff*

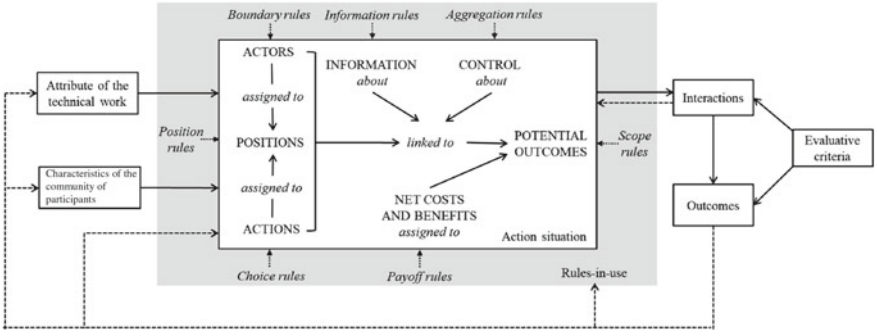

Fig. 1 The IAD framework and types of rules (adapted from Ostrom, 2005, 2011)

rules address rewards or sanctions to certain actions or outcomes, and methods of monitoring and enforcement. *Scope rules* address the scope of project goals, performance measurement, actors' authorised or forbidden domains, etc. The outcomes of the action situation, moderated by the evaluative criteria, feed back to the loop of iteration (Fig. 1).

6 A Worked Example

In the following sections, a project case is presented as a worked example to illustrate how the IAD framework can be mobilised to guide safety capabilities development in a project environment. Project, as defined by Davies (2017: 2), is '*a combination of people and other resources brought together in a temporary organisation and process to achieve specified goals'*. The case is based on reflective analysis of the author's experience of designing and teaching a 'Project Safety Management' unit in an undergraduate programme in 2014 and 2015. The curriculum design of this unit was based on an in-depth review of the latest research in IPD and safety, from which a gap of developing IPD-embedded safety capabilities was identified for the industry. Thus, defining and cultivating such capabilities among the students were a general orientation in developing and performing this unit. Based on a studio-based learning concept (Schön, 1987), the core learning activity was a debate competition game, around which all lectures, guidance, information and reading materials were developed as on-demand resources to support students' enterprise. The game required students to work in groups of 20 to form project organisations to deliver a debate on a critical safety issue in major construction project delivery over a period of 16 weeks. Through the team building and project delivery experience, students were expected to develop the safety capabilities as part of their personal quality to become future project managers that lead a new culture in the industry.

The players of the game were two cohorts of around 100 undergraduate students who were overwhelmingly male and engaged in part-time jobs parallel to their university study. Some had practised in the industry before university. It is fair to describe the actors as being embedded in the masculine and competitive culture of the construction industry, carrying the silo mentality of the traditional practice. The author in this game, as unit coordinator and lecturer of the course, played the role of system designer, system governor and project sponsor.

After setting up goals and initial game rules, students were empowered to develop their own working rules (e.g., organisational structures, roles and accountabilities) bottom-up; while the author joined the game as a project sponsor to steer the development process through governance and support (Crawford et al., 2008) to ensure the right capabilities are developed in situations of deviation and change.

The assignment involved an intellectual task and an organising task. The intellectual task was to develop and perform a safety debate supported by research evidence. The organising task was to walk the talk, i.e. to develop an organisation of collaborative practices that enact the safety values during the project process. In doing so,

each organisation must situate itself in a specific stakeholder's role and understand its core business interest in a construction project before proceeding to identify the debate topic and sub-arguments. The organising task is an organisational structure that enables effective teamwork; this would include defining tasks, dividing roles, and motivating team members to work out collaboratively. The exact pathway of achieving these goals were left to students' discretion to work out with their team demographics. The structures of the processes are illustrated in Fig. 2.

The written reports were required to involve two parts: an intellectual part which presented the topical arguments of the debate and a reflective journal which gave a personal account of the actor's experience in the organising process. As students crafted their own organizational structures and processes, each of them was fitted into a unique role in an unique organizational environment. Each one thus went through a unique experience, from which a personalized set of capabilities were developed. The marking of assignments had been part of the data analysis process. In analysing the assignment submitted, the author first triangulated all the stories on one person to reconstruct the behaviours of each actor, and stories around one event to construct the reality as truthful as possible. The triangulated scenarios are analysed with the IAD framework, patterns of behavioural responses analysed against the action situations to identify the expected capabilities.

In the marking process, the lecturer provided individualised feedback to each student. Students were given an opportunity to initiate an individual meeting with the lecturer to negotiate their marks if needed. This process gave the student actors an opportunity to explain the connection between their intention and behaviour to demonstrate how they had enacted the safety values in participation of the team's organising process. Furthermore, the lecturer strongly encouraged all actors to participate in the university evaluation system, which, was the external institutional environment of this unit. To this point, the lecturer played equal with the student actors as fellow participants of the game.

On reflection of what specific capabilities were developed among the students through this process and how, the unfolding process of the teaching/learning journey can be retrospectively understood as an ethnographic action research (ERA). ERA is a

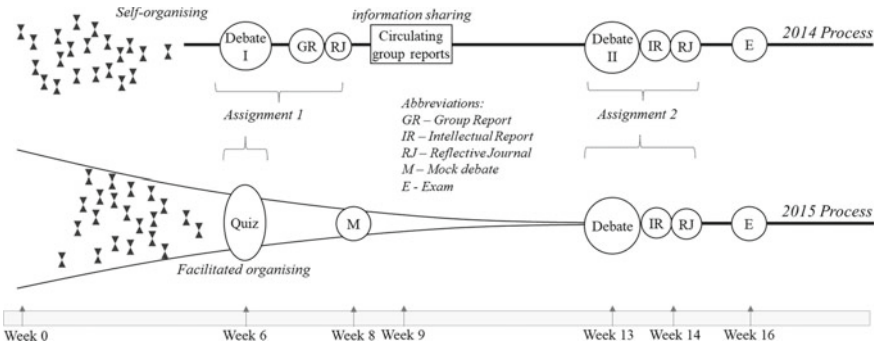

Fig. 2 Structures of the project process in two consecutive years

methodology that integrates ethnography, action research and grounded theory, with a focus on conceptualisation (Hammersley & Atkinson, 2007; Tacchi et al., 2003). Emanated from the Tavistock Institute tradition, ERA is an explorative process in which the ethnographer plays an active role, out of which interventions are organically generated and knowledge is co-constructed (Hammersley & Atkinson, 2007: 159). Amid field dynamics, the ethnographer iteratively learns how a situation works and evolves in its actual structure, culture, practice and relations while making active interventions in his/her legitimate role that alter the situation (Goffman, 1989; Tacchi et al., 2003).

6.1 Dynamically Developed Rules System

The game rules of the project were interactively crafted between the system designer (the author) and the actors (students), summarised in Table 2. At the project front-end, the tasks and the rules system were deliberately underspecified to give ample discretion to actors' self-organising initiatives. They were dynamically constructed during the project process and not developed in full until the end of the project. The completion of the technical task (the debate) in the project was paralleled by actors' rule-crafting activities and the system governor's improvised interventions. Through the interactive experience of developing team structures and routines, IPD-embedded safety values were enacted in actions and substantialised into capabilities within the actors.

6.2 Forms of Self-organizations

6.2.1 Vignette I. Leadership from Self-initiative

Initially, students were greatly troubled by the ambiguity in the task setting, worried for not knowing 'what is the task' and having to team up with so many strangers. The underspecified tasks and rules challenged students with leadership capabilities. However, ambiguity was exactly the breeding ground for self-initiative and self-organisation from which new organisational routines were developed that fitted the team and task characteristics. At this stage, what is needed from the system designer is patience of waiting and courage of 'offering no help'.

Lost in idling for a few weeks, students came to an awareness that they needed first of all to give group members a sense of ownership on the project; and the lack of it was due to an absence of role definition. Once the problem became clear to them, a self-organising process kicked off, students started to craft structures and roles.

Leadership emerged from a self-initiative of reducing uncertainty. For example, one of the team leaders saw people were sitting around having nothing to do, he decided to do something about it. He thus started from writing down everybody's

Table 2 Institutional settings of the action learning project

	Initial setting		Exceptions and improvisations	
	System designer's provision	Actors' discretion	Deviant action (by actors)	Improvisation (by s'designer)
Boundary rules	All must join a group. No individual work is accepted. *Timing* of major milestones, e.g., submission of assignments, was specified.	Roles and change of roles within the group *Timing* of sub-tasks	Trying to go back silo operation or kick out team members of different minds	A 'No-divorce' policy was issued as a boundary condition to dispute situations.
Position rules	*Positioning the groups*: All groups must assume a specific stakeholder's role; a pool of stakeholders' roles is provided as choices *Positioning individuals*: a reference organisational structure is provided	Assume a stakeholder's role of the group's choice; Organisational structure and roles within the group; individual self-leadership	*Two groups selected the contractor's role*	Split contractor's role into two: small contractor and large contractor (main contractor)
Choice rules	An online platform (Blackboard) was suggested for group communication. A 30-min sessions were set aside from the lecture sessions for group meeting	Colocation utilised; craft & adjust organisational structure or working style to work out collaboration	Actors used Facebook group as a communication centre.	Facebook was accepted.

(continued)

Table 2 (continued)

	Initial setting		Exceptions and improvisations	
	System designer's provision	Actors' discretion	Deviant action (by actors)	Improvisation (by s'designer)
Authority rules	Teacher communicates with group leaders to authorise debate topics; announcements and references distributed through Blackboard	Actors decide report lines within the project organisation and self-manage intra-group communication.	Team leaders and chairpersons couldn't agree with each other in some cases.	The teacher step in as an arbitrator
Information rules	Teacher makes weekly announcement through Blackboard; email and face-to-face communication with group leaders; group reports shared to all in 2014	Intra-group communication is left to actors' self-organisation.	Students made the most of the colocation opportunity for meetings; complemented by online platform	One-on-one tutorials with students to provide personalised coaching.
Payoff rules	The first task is assessed by a group mark; the second task assesses individual performance in collaborative work context. Best Organisation Award	*Formal*: Peer assessment by writing up the group organising process in a reflective journal	Any other self-initiatives to engage and motivate teammates to pull their weight. Some leaders decided to exclude slow team members	An additional Best Debate Award and new rituals are improvised. Encourage students to approach the teacher to discuss, negotiate or argue their individual cases. Coping-by-exclusion was given a lower mark in spite of a good product.

(continued)

Table 2 (continued)

	Initial setting		Exceptions and improvisations	
	System designer's provision	Actors' discretion	Deviant action (by actors)	Improvisation (by s'designer)
Scope rules	Assignments involve an intellectual report on the debate content and a reflective journal on the organising process. IPD-embedded safety values are measured in both parts.	Students can demonstrate the acquired capabilities with diverse manifestations	Students' self-initiated informal feedback to the teacher.	Encouraged students to rate their learning experience through the university's standardised system. Students' self-invented feedback was appreciated

name in his organisation, and was subsequently appointed as the chairman to lead the project. Based on his position, he managed to split the group into two teams, an Affirmative team and a Negative Team. The teams went on to craft more specific roles and reporting lines. Depending on levels of prior experience, the chairperson's position to some students was an opportunity of utilising and systemising their past experiences and skills; and to others, an opportunity of getting their first leadership experience.

In this process, students personally experienced the consequences of an organization lacking leadership and roles, in the situation of which they found themselves either repeating each other's work or going for diverse directions. Self-initiatives emerged from a perceived need of clarity, which is to be achieved through coordination, division of roles, work packaging, task delegation, and strategic direction steering. The experience of crafting a mechanism for working together enables students to see why leadership is important in project delivery and therefore the reason of developing it.

As student teams were empowered to develop their own structures and rules, so they learned to empower their team members through trust and confidence. The self-organising experience enabled them to see the link between the organizational routines and the performance of both the individuals and the groups. In the end, the artistries of leadership and management became individual capabilities through the personalised experiences, including how to navigate group interactions, how to communicate and how to empower each other.

6.2.2 Vignette II. Institutional Diversity Inspired by a Reference Structure

As the IAD framework suggests, there is no 'best' organisational structure, rather, effective institutions are those that fit the specific characteristics of the community of the players. Thus, at project briefing session, a hierarchical organisational structure was given to students as a reference structure only (Fig. 3A). The actual organisational structure was left to students' self-formation as it fits the team characteristics.

The groups crafted their organisations in diverse process. Some groups worked out through a top-down process, in which a charismatic leader played a strong hand to assign roles and divide tasks; or a bottom-up process, with team members choosing their own roles. Fig. 3B is a typical self-organised structure, with a chairperson responsible for communication with the teacher and coordination of the sub-teams. Figure 3C is a structure where a group divided themselves by cultural background, with an affirmative team composed of overseas students and a negative team of local students. In this case the lecturer had to take back the leadership and manage the three team leaders separately to make sure the two very different team-cultures work coherently and innovation was not killed by a compliance-minded chairperson. Group D crafted a highly pragmatic organisational structure centred on two major tasks of their categorisation: one team responsible for performing the debate and another for writing the report. In other groups, the three speakers were leaders of the small research teams; while in Group D, the speakers worked as performers only.

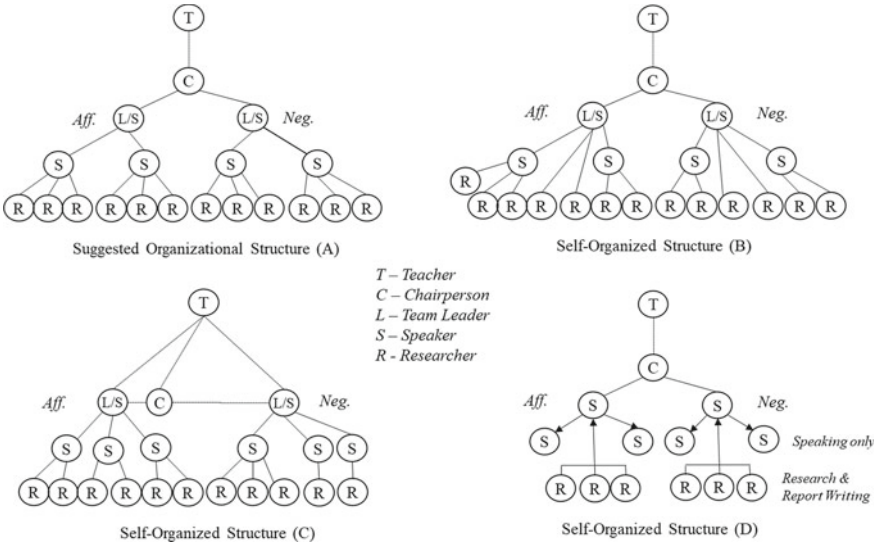

Fig. 3 Reference organisational structure and examples of self-organised structures

6.2.3 Vignette III. Bottom-Up Formulated Information Rules

The groups developed different routines to process information, in a hybrid of colocation and online remote mode. The author decided not to monitor the in-group communication to give autonomy to actors' self-organisation. A temporal space was created to support the organisational activities: the first 30 min of the weekly 2-h lecture time was set aside for group meetings, which was welcomed and fully utilised by the groups for solving problems together. The colocation mode of work was extended outside of the official time and place. For example, a group divided their negative and affirmative teams by their living locations, on the south or north of the major river in the city, for the convenience of face-to-face meetings and discussions.

Complementary to colocation, all groups set up their own Facebook groups to store, communicate and exchange their digital information, including drafts, debate topics, questions, announcements and deadlines, for in-group communication. Group leaders naturally took up the responsibility of an information manager, and made colocation and online communication complementary to each other. The online platform eased the pressure of concurrency and travelling for meetings, and allowed flexibility for individuals to work on their diverse personal schedules. Students realised that a major consequence of ineffective communication was that it impeded trust-building among team members. They learned to handle the situation with perseverance, by defining roles, and by working out two-way communications that enables iterative decision-making.

6.2.4 Vignette IV. Expecting the Unexpected: Capabilities of Learning, Resilience and Forgiveness

Inherent in the operation of the established action situation were unexpected dysfunctions such as team members missing meetings or quitting their speaker's role right before the performance of the debate. The emergency situations demanded the teams to make quick responses, thus became causes for capabilities of organisational resilience. For example, when some team members dropped out of this unit in the middle of the semester, the groups assigned new people to fill in the abandoned roles to keep the work going. In another situation, a speaker was absent (due to traffic) from the debate performance, while a researcher was urgently upgraded to the speaker's role to improvise a speech, which kept the performance running smoothly.

Further the artistry, some leaders learned to 'plan for' emergency. In one group situation, two members noticed their leader that they would not be able to attend an important group meeting due to family issue or traveling outside of the state. The leader handled the situation by preplanning these two members' schedules into the timeline; by assigning clear tasks to them with a deadline before the meeting, so that they could both make their contribution to the teamwork and go away without jarpodising the group progress.

The system became a forgiving system when ordinary team members became mindfully ready to take up a missing function. In one of the debate performances, a speaker suddenly decided not to perform his role for feeling a lack of confidence. As an emergency response, one of his teammates stepped up to fill his role. Students learned from experiences of responding to such emergent situations to anticipate the unexpected, and have the resources ready for tackling unexpected situations. As such, resilience was built into a habitus through the organising experience.

6.2.5 Vignette V. Negotiable Performance, Dialogical Evaluation

Scope rules in this project involved two-way evaluation: the assessment on students' project outcomes and students' evaluation on the project settings and support from the lecturer. The intellectual report assessed understanding on the stakeholder's core business interest, cost and benefit of safety, integrated solution to safety and the need of organisational learning and resilience. Assessment on the reflective journal is concerned with the practice of safety values during the collaboration process; authentic understanding of organisational structure and its change; making sense of one's own role (in-role performance); engaging and caring of teammates (be inclusive, show patience, respect diversity); conflict (handle and learn from it) and crisis handling; boundary management; and reflexivity. The formal assessment was complemented by rituals, awards and flexible feedback mechanisms.

After marking each assignment, the lecturer encouraged students to come forward to discuss, negotiate or argue their marks with the assessor (the author) in individual meetings. If they could convince the lecturer that they deserved a higher mark, then their mark were improved; otherwise, they were convinced that they had received

a fair mark. The negotiable, interactive assessment gave the actors an opportunity to articulate the link between their actions and the safety values in the specific action situations.

After submission of the finalised marks, the author sent around an announcement to encourage the students to become a player of the higher-level system through participating in the university's standardised teaching evaluation system. This helped students' sensemaking of the 'system of systems' and resulted in a much higher rate of participation compared to the parallel units in the same undergraduate programme. Yet furthermore, outside of the university's formal system, students invented their own means of giving feedback to the lecturer. At the end of the semester, student leaders posted on the lecturer's office door a piece of chocolate and a note "Great work Andrea this semester!" with a summary of what they had learned through this project, quoting the French politician Jean-Francois Cope's words, '*I invite everyone to choose forgiveness rather than division, teamwork over ambition.*' Clearly, the safety capabilities had been developed among them.

6.3 Handling Exceptions with Improvisations

6.3.1 Vignette VI. Ensure Actors Are Solving the Right Problem: Facilitate Sensemaking, Enforce Boundary Rules

Typical issues arose in Week 4 when students woke up from idling to worry about the little progress made thus far on the project. Used to being tasked with well-defined problems in prescribed roles, students found the assignment of working with 20 strangers on an undefined task a source of panic and anxiety. An immediate solution to fix the ambiguous situation, to students' knowledge, was to approach the Department to complain about the 'workload', and to demand to assign them to smaller size of groups. Co-thinking with the actors, the author improvised a job-design survey (Van de Ven & Ferry, 1980; Jia, 2009) to understand exactly how much time this project was taking in their weekly schedule. Interestingly, the survey result showed that only 9% in the class felt 'overloaded' (all of whom were group leaders), 59% felt their workload was '*just about right*', while 32% reported '*there were not enough work to keep me busy*' (all of whom were 'researchers' at the bottom of the organisational structures). It was clear that the problem was not about 'workload', but about undelegated tasks that should be solved by effective leadership and team mobilisation. The survey result was fed back to the actors, coupled with an enforcement of the boundary rule that collaborative work at the specified group size was the only acceptable approach of delivering this project; and there was no choice available for silo work. Organisations were advised to review their task allocation, adjust organisational structure, define clear roles, and make effective delegation of the work. From this point, students settled their minds on the collaboration track and started to develop necessary capabilities to work out in collaboration.

In the second year, when the same action situation was given to students, the same deviation was repeated with more intelligence: the lecturer was surprised to find

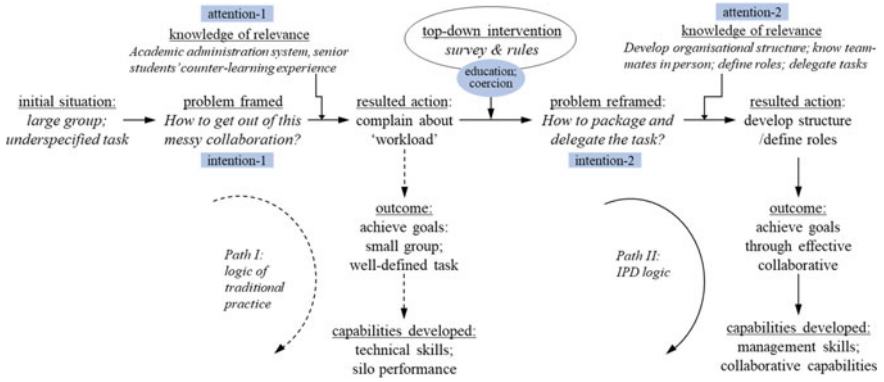

Fig. 4 Summary of the deviations and interventions in Vignette VI

students learned to manipulate the survey! The new cohort of students were informed by their seniors how the survey worked, and subsequently invented a countermeasure to quit collaboration: a few group leaders organised their friends to exaggerate the number of hours filled in the survey and used a self-selected sample, as evidence, to back up their 'workload' complaint to the Department. In this instance, a major lecture was improvised to communicate a more explicit vision of this project and individual personal career prospectus to help with actors' sensemaking. At the end of the lecture, students were able to reframe the problem in their mind from "*how to quit this messy collaboration?*" into "*how can I improve to be able to excel in this collaboration*?"

In this process, students' deviant actions exhibited a consistent pattern that enacts the logic of traditional exclusive practice in the industry. Top-down intervention was made through education to facilitate sensemaking, coupled with coercion of the boundary rules to help the actors to focus attentions on collaboration and to embark on an alternative course of actions that enact an IPD logic (Fig. 4).

6.3.2 Vignette VII. Alternative Dispute Resolutions: Capabilities of Inclusivity

While actors were given ample freedom to craft their own rules and debate contents, the system governor (the author) invested a large amount of time to attend conflicts and disputes that occured during the collaboration process. A normal reaction to conflicts and disputes was to lay blames on each other or to kick out difficult team members. The system governor, in attending to such requests and complaints, worked tirelessly to direct actors away from the conventional approach of blame and exclusion toward personal growth of leadership and new capabilities.

After the first debate in the 2014 project, a major intra-group conflict broke out in the group that represented Small Contractors' interest. One of the members abruptly quitted his group and posted a complaint on Blackboard against his teammates, citing

the university's new anti-bullying regulation. This publicized complaint caused much anxiety among the team leaders, who in reaction wanted to altogether kick him out of the group and deprive his right to share the group mark. The issue was brought to the lecturer's attention. The author started with separate discussions with the disputing parties, through which she found that the complaining student was a latecomer to the group, was six years older than his teammates, and had rich experience in his family business as a Small Contractor. Whilst his experiences could be an invaluable resource to the group, the younger members however had formed their own team culture and routine before his arrival. Embedded in his experience and background, he perceived the group leaders' instructions as naïve and inappropriate, therefore he was unable to follow; yet he had not the leadership or legitimacy to lead his young peers. So, during the teamwork, he ended up either trying to correct everybody's work or trying to do the work all over again by himself. Thus, his teammates considered him as an interruption and managed to get the work done without him, which was perceived on his side as exclusion and bullying.

After the initial exploration, the lecturer personally coached the disputing parties to see opportunities of capabilities development in handling this conflict. When both sides expressed willingness to reconcile, the lecturer issued a "no-divorce" policy to the class to enforce the boundary and choice rules to mandate collaborative solution in dispute situations. As 'claim', 'blame', 'withdrawal' and 'exclusion' were ruled out from the available choices, actors started to focus their attention on developing leadership skills to understand, engage, motivate and collaborate with their teammates of diverse characteristics.

The group worked out collaboration by adjusting roles and report lines and going an extra mile to embrace diversity. Within this institutional framework, the values of inclusiveness were substantialised in new capabilities. The team leader re-considered the strength and skills of that member and promoted him from a researcher's role to a speaker's role in order to engage and motivate him. Within the group, all team members made extra efforts to listen to and understand one another's point of view to achieve mutual respect. The report line had also been adjusted so that the unsatisfied team member could work with a leader that he was more comfortable with. On the other side, the once-dropper-out member learned to accept his less experienced peers. In this case, deviant acts arising from the incompatible characteristics of the project participants were redirected to the IPD course of actions by top-down interventions through facilitation of sensemaking and coercion of the boundary rules (Fig. 5).

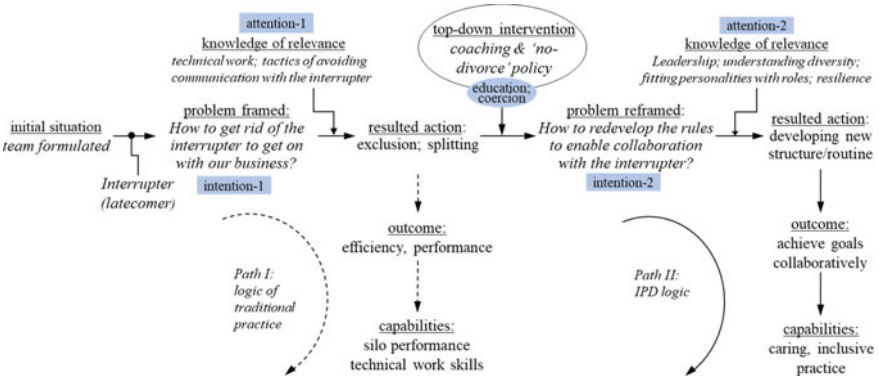

Fig. 5 Summary of the deviations and interventions in Vignette VII

7 Discussion

7.1 Taxonomies of Rules

The worked example serves to illustrate how the contextualisation of the IAD framework for analysing and developing project governance mechanism (Müller et al., 2015). So far, institutional analysis on construction projects has a focal interest in the formalities of institutions, which helps us to examine the informal rules on a compatible platform with the formal rules (Scott, 2008; Bygalle et al., 2015). The IAD framework goes further to classify rules into seven types by their effect on actions, enabling more specific insights into the link between rules and their behavioural consequences. With this taxonomy, we can distinguish different contract forms in procuring a construction project. For example, it enables us to see that boundary and pay-off rules make a difference between a design-build project and an IPD project. Consider this scenario described by a practitioner, '*I've seen some fantastic design and construct contracts go really well, great relations and at the end (when) the claims start to come in because the bottom line hasn't been realised…things start to really go sour and all that positive energy suddenly gets diverted into negative stuff and the relationships start to fall away*' (practitioner's interview by Walker et al., 2017: 188). The scenario indicates that under a design-build contract, team integration has a time limit because the boundary rule is not set in a way to involve client in the project team. Claims and disputes lurk around the corner waiting to break the trust between the client and the project team when the project comes to the completion stage. In an IPD project, the pain/gain share rules ensure client is part of the team; the pay-off rules stress interdependency among actors. "*…if I make a decision, how does it affect my trade partner? Do their costs go up because I made a decision for my costs to go down*?" (quoted from practitioner's interview by Hall et al., 2018: 9). The initiative of this study is to help learners to make a shift from the existing silo mentality to the new IPD mentality. The rules taxonomy provided

by the IAD framework has enabled us to discern the key rules in diverse situations, prioritise and focus on key institutions to guide actions.

7.2 An Inclusive Project Front-End as Driver of IPD-Embedded Safety Capabilities

The results indicate that the development of IPD-embedded safety capabilities involves learning of the new logic and unlearning of the old logic. An open front-end plays a key role in this process. An inclusive project front-end allows the old logic to be deconstructed, redressed, and unlearned. Actors need to be given the discretion to define the problem on their own, therefore be exposed to the opportunity to reconstruct the existing logic in their mind. The initial situation of this project is a typical project front-end situation characterised by ambiguity and uncertainty; the under-specification of rules at this stage left ample space for bottom-up institutional development, starting from defining the project missions and values (Morris, 2013; Winch & Leiringer, 2016). Thus, an effective strategy for team integration and capability development is to open up the front-end to define a more inclusive goal for the project. Precedents are found, e.g., in Sutter Health's California project which, by involving the architect, user, owner and contractor at the project front-end, brings relational factors, project learning and innovation into the project success criteria (Tillmann et al., 2012); and the Liekki project in Finland, which formulates a shared project identity by involving major actors in '*a period of intensive search for a joint meaning and shared purpose*' at the mobilisation stage (Hietajärvi & Aaltonen, 2018: 14).

Orr and Scott (2008) suggest three stages in the cycle of an institutional exception, including (1) institutional ignorance which is materialised in surprise and deviant acts; (2) sensemaking which is materialised in knowledge searching behaviour, and (3) response, through enactment of a new mindset. In their model, sensemaking happens after the recognition of the institutional exception and stops when a response is enacted. Findings of this study suggest that the deviant acts are part of actors' sensemaking process, as an enactment of actors' conventional logic. Top-down interventions are needed in situations of deviations to redirect the actors to the right course of sensemaking (Weick, 1995, 2012; Weick et al., 2005). For example, in Vignette VI, the actors first framed the ambiguous front-end situation into a problem of 'workload', which mobilised their knowledge about the university system to reach a solution of making a complaint. This initial reaction to the demand of large-team collaboration mirrors practitioners' initial reaction to an IPD environment, as described by a manager, '*Working in a collaborative environment was …a huge cultural shock. About 9 months into the program I recommended that we actually got out of the framework*' (Tee et al., 2019: 55).

7.3 *Capabilities Development as a Process of Institutional Change*

Focusing on institutional development actions, our findings point to a perspective to see the development of IPD-embedded safety capabilities as a process of institutional change or the transformation of institutional logic. The process occurs as 'institutional exception', defined by Orr and Scott (2008: 563) as '*an entrant first being surprised by, then making sense of, and then adapting to institutional differences*'. Institutional exceptions are not deliberate transgressions of rules but are triggered by actors' ignorance to a new institutional context. Hence the initial encountering of the situation is always beyond the actors' comprehension, and the handling of it must involve knowledge searching behaviours (March & Simon, 1967 [1958]).

Orr and Scott (2008) define two interacting parties in an institutional exception, the entrant and the host. The former refers to the foreign project managers and the latter the local institutions in the case of global projects. This definition assumes a static division between the project and its institutional environment. In the case of IPD, the project creates an institutional context which is exceptional to the existing industry culture embedded in the project participants' minds. Therefore, in a sense, the IPD project sponsor is a host to the traditional-minded participants and is an entrant to the existing industry context. Results of this worked example of the IAD framework stress the effect of embeddedness; and the necessity of a mutual learning process between the actors and the system designers. There were good and bad exemptions in this case; the former was actors' creative development of rules-in-use; the latter was actor's misconceptions of the situation and the deviant acts prompted as solutions. In this project process, good exceptions were accepted and integrated into the system, bad deviations were redirected by sensegiving and holding up the boundary rules.

The deviations in this project process suggest that misconception of the situation is not random but is consistently sprung from actors' existing embedded logic. The development of the new capabilities involves learning of new values and unlearning of old values (Argyris, 2003), and a shift in attention (Ocasio, 2011) and course of sensemaking (Weick, 1993). This process is characterised by constant trials-and-errors which slow down the project at the front-end. There is a time cost to be expected for the transformation of logic (Thornton, 2004; see also Orr and Scott, 2008 on the discussion of the cost of handling institutional exceptions). Actors tend to go back to silo practice in uncertain situations because silo is the efficient and effective way of problem solving that they are used to. The logic they are currently embedded in is not efficient, but it is an efficient way for them to solve immediate problems. The transformation involves a paradox: actors have to give up their desire of immediate efficiency in order to achieve the right capabilities for a more efficient project delivery. Things have to slow down before they can speed up. The logic they are supposed to enactpick up will produce more efficiency, but they need to go through an inefficient period of time, or a time of wondering and searching, to gain the right capabilities to materialise the logic. A strong desire for immediate efficiency stops learning.

7.4 Division of Power Between Top-Down and Bottom-Up Institutional Development

The division of power between top-down and bottom-up institutional development emerges to be a core factor that enables capability development. Davies and Brady (2016) suggest that project capabilities are not developed solely by top-down actions, but through a process of evolution and change in the iterative reciprocities between strategic and operational actions. The finding of this study suggests that projects can consciously plan out a space of discretion for local actors' bottom-up crafting of rules to foster actors' capability growth. The discretion enables institutional diversity that fits varied characteristics of project teams with each unique project context.

Here, the division of power does not mean the division between formal and informal institutions. There are informal institutions given top-down, e.g., individual consultation, and formal institutions crafted bottom-up, e.g. the organisational structure within each group. The power division is about 'who' make the rules. The division of power allows the project sponsor, instead of assuming a once-for-all imposition of an IPD system, to learn about the characteristics of the project team over the project process, and improvise the needed institutions that fit the specific team. For example, the hybrid of colocation and online platform for communication and how they are used to complement each other differs by the available technologies, team preferences and technical capacities across projects. The learning is mutual, interactive and iterative between the top and the bottom (Fig. 6).

The division of power finds justification from the trust building process in construction project delivery. A key issue with trust building among project stakeholders is *who* make, and therefore own, the rules (Jia et al., 2017). Top-down

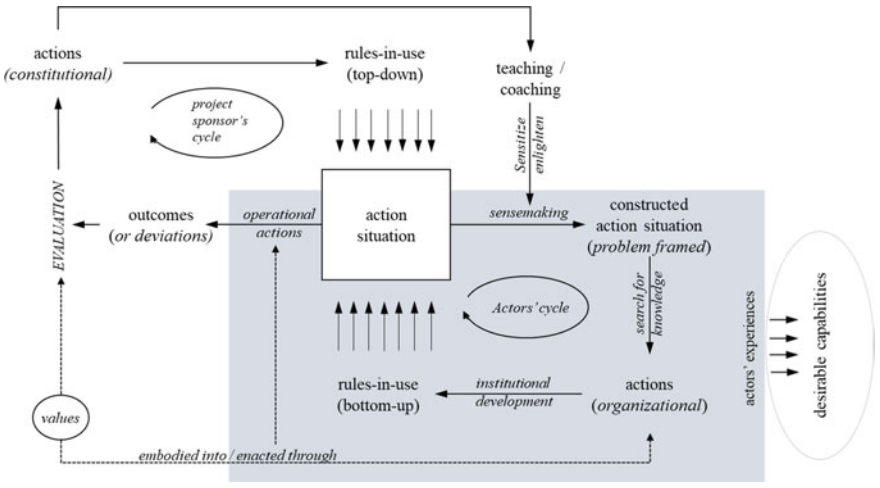

Fig. 6 The process of capabilities development based on the IAD framework

imposed rules-in-use often take away ownership from the rule-practicers, enforcement perceived as distrust (Bresnen et al., 2005). Empirical studies on IPD projects find that poorly defined roles from *ad hoc* practice, uncoordinated responsibilities and inadequate processes are largely accountable for conflicts and unreliable decisions in project delivery (Zwikael & Smyrk, 2011; Tillmann et al., 2012). Project actors need clear roles to establish 'swift trust' (Meyerson et al., 1996; McLaren and Loosemore, 2019) in the limited time span of a project (Grabher, 2002; Jones and Lichtenstein, 2008). In a conventional project environment, the defining of roles can be simplified by referring to the professional and organisational boundaries, hierarchies and routines. In an IPD environment, the conventional boundaries are blurred, flattened or dismissed; the new categories need to be redefined and crafted according to actors' characteristics and project context. Thus, individual capabilities of defining roles and boundaries in dynamic situations are particularly important in the delivery of IPD projects (Fellows & Liu, 2012). The institutional development discretion given to the community of actors, as tested in this study, allows mutual learning between the system designer and the project team. It helps establish the swift trust by enabling diverse actors to be better understood, roles to be organically constructed and fitted, to bring along a strong sense of ownership among the project team. In terms of system learning, Fig. 2 shows that the second year's system design learned toward accommodating the actors' desire of being given a more prescriptive structure, but the result was less effective system for capability development compared to the more generic setting of the first year. This result further illustrates the dynamic of mutual learning. System learning does not necessarily move towards better and optimal. Every iteration involves a dynamic fitting between the system and the community of actors, anchored in the goal of development.

7.5 Learning as Shifting Logic: Improvised Interventions for an Alternative Course of Action

From an institutional logics perspective, the major constraint to IPD practice is the lack of understanding of many practitioners on what IPD seeks to achieve and how it may do so, as their attentions are quarantined in the logic of conventional silo practice (the 'mirroring trap' as defined by Colfer & Baldwin, 2016 and discussed by Hall et al., 2020). The mirror-breaking process involves a change in cognitive frames through a shift of focus in actors' intention, attention and sensemaking (Thornton et al., 2013; Jia et al., 2017). New capabilities start to develop from a change in actor's intention, manifested in the change of problem framing (Kvan and Gao, 2004). This leads to a refocus of attention, perceived by the actors as what knowledge is relevant, what the actors look for and how they make sense of the available resources (Jia et al., 2017). In this study, two alternative cycles of sensemaking among the actors are apparent. As shown in Fig. 7, Sensemaking cycle 1 is when actors encountered a surprise in their situation, upon which they develop a solution out of their

immediately available coping strategies. Such actions are prompted from the institutional logic they are used to, which is a deviation from the learning objectives. The capabilities developed from such reactive experience are enhancing the conventional logic, are counter-collaborative and undesirable. Sensemaking cycle 2 is the instance after intervention where the actors start from framing the right problem, embarking on the right track. The initial setting was supplemented by the improvised interventions to direct actors' actions to foster the new logic. In this process, the system designer focused on two key courses of actions: setting up an inclusive project front-end and improvising interventions over deviations. Effective intervention to actors' withdrawal from collaboration is to hold up the boundary rules to stretch capability development, coupled with a more subtle sensegiving intervention that enlightens practitioners to align means and ends while keeping their ownership to the rules. Options of silo-operation must be excluded from the repertoire of coping before the traditional-minded actors can set their mind on developing means of collaboration. Once intention turns around, a different set of knowledge enters into actors' attention; the situation made a different sense to the actors. The right capabilities grow out of actors' experience in the new course of sensemaking. To achieve the goals while navigating through the new institutional context, actors acquire new skills, information and knowledge, or reconfigure existing ones, from which new capabilities develop (Grabher, 2002; Davies & Hobday, 2005).

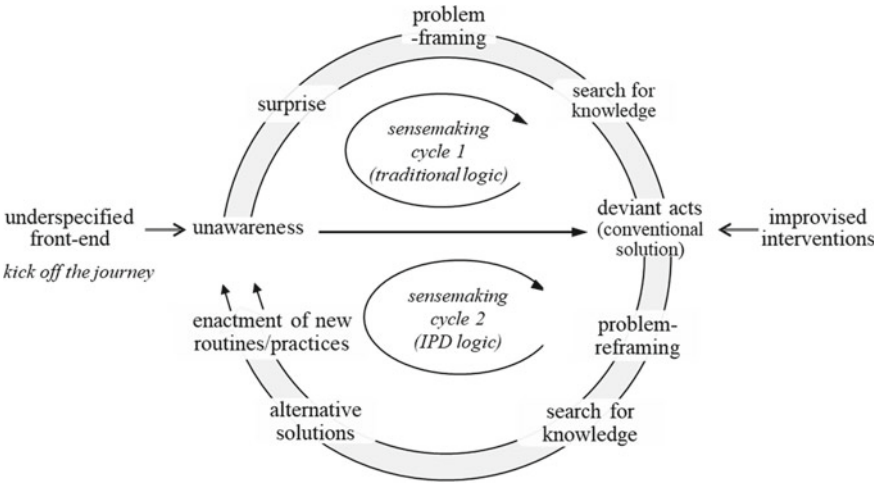

Fig. 7 The actors' sensemaking cycles

8 Conclusions

This chapter introduces the IAD framework and provides a worked example to illustrate how it can be mobilised to guide development of safety capabilities for IPD practice. It does so by creating a cause (a technical task and team condition) and an institutional environment (rules-in-use) that incentivise capability development. Seeing safety as an integral attribute of IPD system, a broader safety concept is defined, which is essentially a caring, inclusive and forgiving system carried out by collaborative practice. Accordingly, a set of IPD-embedded safety capabilities are defined. The key challenge to the actors in this process is to 'walk the talk', i.e., to make sense of and live out the safety values in their project organising practice that enact an IPD logic. The research contributes to a better understanding of institution theories and how it works in a project management setting. The process suggest that, by mindful design of an inclusive project front-end and sensible guidance, the system governor can motivate and direct actors in their acquisition of safety capabilities for IPD practice. In doing so, a conscious division of power between the top-down design and the bottom-up crafting of institutions need to be carefully considered and sensibly managed during the project process in order to incentivise collaboration and capabilities development. Equally important is an inclusive project front-end that engages actors in activities of problem-framing, which makes it a breeding ground for learning, innovation and capabilities development. The methodology is generalizable to the teambuilding stage of IPD projects.

Practically, the research provides a guidance on the formation of action situations that make IPD project a vehicle for new capabilities development. Trainers of IPD practitioners need to be aware that in an industry that the current culture is predominantly silo, competitive and fragmentated, an IPD project is an 'institutional exception' to most of the practitioners. The development of IPD related capabilities is to replace the traditional logic that actors are deeply embedded in with a new logic that they do not yet fully understand. Thus, IPD project sponsors and trainers should anticipate a significant number of deviant acts from practitioners' responses, sprung from the repertoire of their existing experiences, which need to be sensibly redirected to trigger knowledge searching behaviours toward enactment of a new logic and development of new capabilities. By making every IPD project a vehicle of alternative experiences for the involved practitioners, we can accelerate the diffusion of 'systemic innovation' of IPD, bringing new problem frames and solutions into their attention, through which to transform the industry culture. At individual level, the study suggests that project managers need to build a personal repertoire that enable them to improvise sensible interventions in diverse, evolving and dynamic situations to direct the 'deviant team' back to the IPD logic. Future research is invited to apply the IAD framework in analysing complex construction project processes.

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