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Safety Violations of Construction Workers: An Empirical Study

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Abstract

There are limited studies related to safety violations among Hong Kong construction workers. This study seeks to fill a gap in previous research and provide insight into the current safety violation phenomenon by examining the causes of safety violations. A mixed-method strategy is adopted for this study. The quantitative questionnaire survey, with 365 valid responses, examined the relationships by adapting the framework of the Theory of Planned Behaviour. Thirty-seven semi-structured interviews were then completed to explore the phenomenon. The findings show that intention has a significant impact on safety violations. Two proximal factors (perceived behavioural control (PBC) and attitude) significantly influence their intention, with PBC being the most significant factor. High Reliability Organising, which is the distal factor contributing to PBC, attitude, and descriptive norms, offers a new era of construction safety management that requires a sense of reflectiveness for ongoing improvement. To enhance workers' intentions, practical interventions can be developed that focus on PBC and attitude. Training should be tailor-made to cater to the specific characteristics demonstrated by different work groups such as young and elderly workers. The government should also review the current weaknesses of safety training.

Keywords: safety violations; safety compliance; theory of planned behaviour; high reliability organising; engagement; training; safety management

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1. Introduction

Although there has been significant focus on safety in construction, the decrease in accident rates has levelled off in recent years. This situation is found globally, including Hong Kong. Unfortunately, this proposition is still totally valid with reference to the latest statistics from many different countries [1]. Construction is well known as one of the most dangerous industries due to its characteristics. For instance, the Australian construction industry is depicted as (1) being male dominated; (2) staff required to work long hours; (3) staff are required to work in remote locations, particularly those who are project based; (4) tight programmes and deadlines to be met [2]. These changing, dynamic, and high-pressure environments are also frequently encountered in various locations. Similarly to Kuwait [3], subcontractors are extensively used, and most construction firms are of small size in Hong Kong. These dangerous characteristics can be identified worldwide.

There are some unique features in the Hong Kong construction industry. The "can-do" attitude of the workers creates a vicious circle in which they do not object to irrational

requests from their bosses regarding progress and cost. The progress of building on four-day cycles is rarely achieved in many other places [4]. The ageing workforce in Hong Kong highlights the benefits and drawbacks of employing older workers in the construction industry. Although they have richer experience and produce more high-quality workmanship than their counterparts, their safety behaviour and fitness are weaker, and they are reluctant to change [4]. Human, particularly in unsafe behaviours among construction workers, is described as a key factor in construction accidents [1].

1.1. Safety Violations

In terms of human failure, violations and errors are two major forms [5]. People not following the rules intentionally are considered violations, whereas errors are unintentional [6]. The concept of violations attracted much attention after the occurrence of the Chernobyl nuclear plant disaster that resulted from human actions and intentional deviations from rules and instructions (violations) instead of errors of judgement [7]. Violations are more specifically related to safety rules and procedures since safety violations occur because rules exist [8]. In contrast, safety compliance is explained as general safety behaviour in Hayes et al. [9].

The factors affecting safety violations have been investigated to understand why violations happen. For instance, the factors influencing construction workers' unsafe behaviours in railway tunnel engineering projects of China were categorised into three major aspects: organisational management, safety environment, and individual safety capacity [10]. However, the causes of safety violations are inconclusive from the literature as there is still little consensus on what variables cause violations [11]. The complexity of reality is depicted well by the concept of "socio-technical systems" based on the interactive influences of work relations and technological factors [12]. Despite this complexity, some studies have attempted to categorise the factors affecting safety violations more systematically, and the factors range from micro (individual), meso (group), and macro (organisational) (e.g., [9,11,13]).

Safety violations are often not as apparent as other risk behaviours. For example, signs and symptoms of recent drug use can be observed more easily when compared to workers who violate some safety rules at construction sites. Contradictorily, construction workers are required to take breaks when the government issues a heat stress alert; however, they often continue working to catch up on site progress. The effects are also more complex and still far from well established in previous studies because they relate to what rules and procedures have been violated, including particular circumstances, at construction sites. For example, if construction workers do not wear a safety helmet at all times, their injury levels would depend on the nature of the work and the site environment.

Their effects are unclear for the following reasons: (1) There is not a well-established link with unwanted outcomes. (2) Violations do not always lead to unwanted outcomes; for example, workers are not allowed in enclosed areas. Still, they would not always be injured and complete the task even if they violate this safety rule, as they may be mindful of moving machines or if some unnecessary space is enclosed. (3) Not all violations are wrong [11]. Non-compliant behaviour in the "grey zone, between control boundary and safety boundary" can be categorised as "risk-adjusted non-compliance", which refers to workers' concern about safety in mind while adjusting behaviour based on their perception and risk assessment of the situation [14]. Safety climate and transformational leadership are negatively associated with safety violations, but transactional leadership is positively related to risk-adjusted non-compliance.

Some studies have applied the Theory of Planned Behaviour (TPB) to analyse different violation behaviours, e.g., driving [15], railway procedures [16], pedestrians' traffic regulations [17], adolescent misuse of alcohol [18], and sorority high-risk alcohol consumption [19].

1.2. Theory of Planned Behaviour (TPB)

The Theory of Reasoned Action (TRA) was originally developed to explain human behaviour in specific contexts [20]. The TPB was extended from the TRA, with control beliefs and perceived behavioural control (PBC) included, which assumes people have full and volitional control over their behaviour [21]. TPB suggests that intention is the closest predictor of human actions, meaning the readiness of individuals to carry out a particular behaviour [20]. Ajzen [22] explains that actual behavioural control (encompassing various internal and external factors) moderates the effect of intention on behaviour; however, these factors are often difficult to measure, so PBC is adopted as a proxy for actual control. Both PBC and self-efficacy are similar concepts about people's beliefs in their ability to perform a behaviour. Still, they are assessed differently as self-efficacy is more specifically related to "a graded series of potential obstacles to performing a behaviour and the likelihood that respondents can overcome them" (Bandura, 1977, as cited in [22], p. 317).

According to the TPB, intention is influenced by three cognitive determinants, which are (1) attitude, (2) norms, and (3) PBC. Attitude can be understood as the worth of that behaviour. Norms pertain to how others perceive the behaviour (subjective norms) and whether they would engage in it (descriptive norms). The initial version of the TPB only considered subjective norms. Some recent studies, such as the one by Fugas, Silva, and Meliá [23], examine both aspects of norms of coworkers and supervisors separately. PBC refers to how people believe in their ability to perform. Haslam et al. [24] illustrate that workers are unable to always control their safety behaviours completely and volitionally as teams, workplace, materials, and equipment interact with each other.

The TPB has been widely adopted in different research areas in recent years, including the studies related to the construction industry, e.g., an integrated training approach to first aid [25]. While the TPB has been extensively studied, it has not been adapted to offer insights into safety violations among construction workers in Hong Kong in numerous research efforts. Yao et al. [26] examine the adapted TPB with the incorporation of personal risk preference on intentional unsafe behaviour of prefabricated construction in China. This study justifies the use of the TPB and highlights the significance of personal risk preference. Exceptional examples like Peng and Chan [27] identify the significant impacts of PBC and subjective norms on older construction workers in Hong Kong, with safety knowledge, management commitment, and ageing expectation having significant impacts on cognitive determinants.

Based on the assumption of sufficiency, attitude, norms, and PBC, it would be sufficient to secure an accurate prediction of intention. General dispositions like personality are viewed as background factors and hypothesised to be mediated by the variables in the TPB model. On the contrary, additional predictors should only be included with caution [22]. From the literature review and consideration of the context of the Hong Kong construction industry, the following two concepts are essential to depict the current condition.

1.3. Perceived Quality of Safety Rules and Procedures

The perceived quality of safety rules and procedures is relevant to safety violations as rules are not consistently effective and applied appropriately in all circumstances [28]. Cox and Cheyne [29] suggest that how workers think about safety rules and procedures affects their safety level. Reasonable rules and procedures should have correct aims and objectives, application, and presentation that prevent employees from violating them [30].

The level of rules should be determined based on the specific situations and abilities of users [31]. Safety rules and procedures might seem suitable for management and professionals, but they fall short for workers because of the subcontracting system. It is reasonable to suggest that by holding other variables constant, safety violations are negatively correlated with the quality of rules and procedures, i.e., safety violations are more likely to occur when construction workers perceive the quality of rules and procedures to be lower.

1.4. High Reliability Organising (HRO)

Attitude, norms, and PBC are considered as micro factors in the TPB. In the Hong Kong construction industry, its nature is temporary, so the organisational factors, such as management commitment and organisational policy, would be more remote. Nevertheless, previous research of the construction industry in various countries highlights the role of project organisations and safety climate, such as China [32], Hong Kong [33], Pakistan [34], and India [35]. For instance, external factors are often filtered by organisations to influence employees' behavioural decisions.

Organisational climate can be a key environmental stimulus in managing compliance of international construction projects [32]. Organisational climate lays the groundwork for safety climate, and both participative decision-making and perceived organisational support are positively related to the perceived safety climate [33]. Safety climate supports construction workers' safety knowledge articulation, which enables them to notice nonconformities and eventually achieve safety at work [34]. Worker safety behaviour was significantly affected by the psychological construct of safety, which is a key aspect of safety climate and refers to an individual's mutual safety obligations, whereas the safety system and co-worker safety behaviour significantly contribute to the psychological construct of safety [35].

To deal with the uncontrollable and invisible risk, HRO thinking, which promotes heedfulness, mutual checking, and initiative, rather than simply complying with the rules, is recommended [36]. Recent studies suggest the application of this concept to the construction industry. For example, Harvey et al. [37] advocate that construction organisations incorporate employee-level individuals for enhancing resilience with respect to the "adaptive age of safety", which aligns with the HRO perspective analysed by Xu et al. [38] that construction companies should investigate existing shortcomings in safety training while enhancing and cultivating a mindful safety culture to transform into high-reliability organisations.

HRO can be understood as the capacity to foresee and manage unforeseen occurrences within an organisation [39]. The main principles of HRO are as follows: (1) preoccupation with failure; (2) reluctance to simplify; (3) sensitivity to operations—focus on anticipation, i.e., prevent disturbing un-expectancy; (4) commitment to resilience; (5) deference to expertise focus on containing unexpected events when they continue developing [39]. Sensitivity to operations can be viewed as situational self-awareness in the construction industry. Awareness refers to "the emotional ability to perceive and concentrate on the presence of an object regarding its characteristics and context" (Bower, 1990, as cited in [40], pp. 7 of 20).

Self-awareness is operationalised differently depending on the research focus, and it can be broadly defined as situational and dispositional self-awareness [41]. The frontier refers to how people compare current actions with internalised standards and adjust to reduce discrepancy (Silvia & Duval, 2001, as cited in [41], p. 646). On the contrary, the latter refers to an attribute-like inclination for psychological processes, inner experiences, and relationships with others (Fenigstein et al., 1975, as cited in [41], p. 646). Therefore, it shows that the concept of mindfulness has a broader meaning than situational self-awareness itself.

From the above, it suggests the conceptual differences between attitude and self-awareness, where the former focuses on the viewpoint of a behaviour (safety compliance/violations within this context), while the latter captures the emotional capacity and process, i.e., how construction workers compare their work to internalised standards and whether any adjustments are required. Nevertheless, attitude and self-awareness are related concepts regarding the proposition of the TPB. Based on the assumption of sufficiency, attitude and PBC are considered adequate for obtaining acceptable accuracy. The HRO was originated to explain other high-risk industries. Harvey et al. [42] discuss obstacles and opportunities of applying HRO and resilience engineering in the construction industry and urge such application under the current adaptive safety age. Therefore, the HRO concept can be categorised as the distal, organisational factor affecting safety violations of Hong Kong construction workers.

1.5. Research Aim and Objectives

As the number of relevant studies is limited, this research aims to fill the existing research gaps by providing insight into the current phenomenon of safety violations. When compared to other studies, this study adopts the HRO mindset, which refers to mindfulness and reflectiveness for improving construction organisations. Instead of the workers being entirely liable for their safety behaviour, it takes "two to tango". All stakeholders should collaborate and enhance workers' safety engagement. The HRO also represents a new age of rules management, where strict compliance would be inadequate to achieve continuous development in the long term.

Examining the factors contributing to safety violations would be the primary research objective. In addition to testing the research framework, the second research objective is to investigate the interactions between safety violations and construction workers in Hong Kong in greater detail. Workers' open views need to be understood to achieve this objective. By adopting a mixed methods strategy, the results validate the adaptation of the TPB in this context, which examines different levels of influences on construction workers' safety violations, including micro, meso, and macro factors. Intention, PBC, attitude, and HRO, were identified to be significant. The interview also revealed the workforce dynamics, current safety training weaknesses, institutional issues, and some unique phenomena in the Hong Kong construction industry.

Although this study focuses on Hong Kong as a study area, the results can also be applied to understand safety violations among construction workers in other countries and compared with studies conducted elsewhere, as similar characteristics are identified across the construction industry in different locations (refer to the beginning of Section 1 Introduction).

2. Materials and Methods

2.1. Mixed Methods Strategy

The research problem determines the choice of a research design [43]. To achieve the research objectives, a mixed methods approach, incorporating both quantitative and qualitative research strategies, was utilised. Researchers should be sensitive to the research context and phenomenon; multi-method studies can be conducted to understand respondents' thoughts [44]. For instance, Alper and Karsh [11] recommend using multiple methods for understanding safety violations since it is simple to count them but difficult to analyse their causes via observations. Elosta and Alzubi [45] adapt the TPB to examine safety leadership and safety behaviour of construction workers and suggest that future studies adopt the use of mixed methods to enrich understanding.

The selection among different research methods is based on their strengths and weaknesses, as well as their feasibility in terms of resource availability and site accessibility. For the quantitative approach, the hypotheses were developed based on the adapted TPB model and then tested through a questionnaire survey. Statistical analysis was used to examine the variables' relationships in the research model and provide generalised findings. Although the questionnaire survey seems to be a traditional research method, it can obtain a large number of responses cost effectively. The results can also be discussed and compared with those of other studies.

After that, interviews were carried out for the benefit of the qualitative strategy. The qualitative approach helps consider all possible variables, their influence levels and combination effects [46], complex issues, and theories and models' linkages [47]. Rhodes [48] also urges using a qualitative strategy for questioning and complementing dominant scientific constructions in the study of risk behaviour. The interviews disclose the construction workers' views openly. The interview results aid in the interpretation of the questionnaire results and offer a rich context to understand the safety violations of Hong Kong construction workers. When compared to other qualitative methods, such as ethnographic and case study, which require staying for extended periods on construction sites, interviews can provide in-depth views on safety violations from respondents working in different construction projects with a greater willingness to participate from construction companies.

2.2. Research Model and Hypotheses Development

This study uses socio-technical system thinking to discuss the root causes at different levels (micro to macro). Based on the literature review, it is reasonable to suggest that after considering the unique context and careful interpretation of the findings, the TPB can be developed as a distinct research framework to analyse the safety violations of Hong Kong construction workers. Although it is acknowledged that the Hong Kong construction industry comprises unique contextual factors, based on the assumption of sufficiency advocated by Ajzen [22], the original TPB has been adapted by only incorporating (1) descriptive norms with subjective norms, (2) perceived quality of safety rules and procedures, and (3) HRO in the research model. In addition to safety violations, this study also examines safety compliance and participation. The research model and hypotheses are visualised in Figure 1, with the description of each construct and hypotheses listed in Table 1 for information. The variables' measurement items were then developed from the previous studies to suit this context. The question numbers (e.g., four questions—I1 to I4 for intention), sources, and short descriptions of measurement items in the questionnaire survey are also summarised in Table 1.

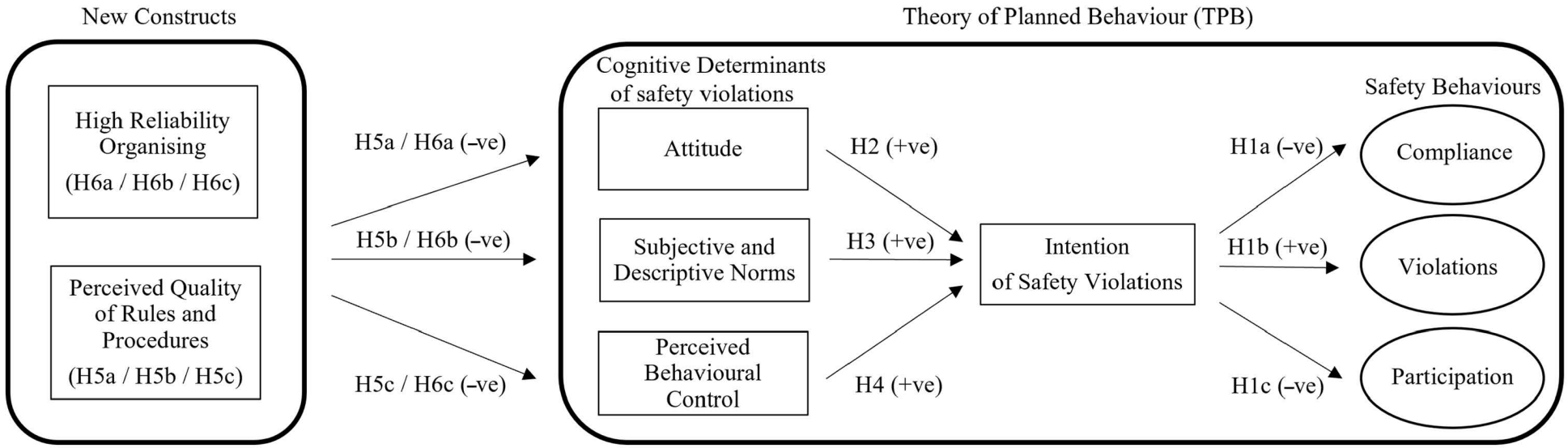

Figure 1. Research model adapted from the TPB.

Table 1. Hypotheses and measurement items developed in the questionnaire survey for measuring the constructs.

Construct	Description	Hypothesis	Short Description of Measurement Items
Intention of safety violations (I1–I4 [a]) [49]	Intention can be affected by three proximal factors (attitude, norms, and PBC).	H1a: Intention (of safety violations) has a negative impact on safety compliance. H1b: Intention (of safety violations) has a positive impact on safety violations. H1c: Intention (of safety violations) has a negative impact on safety participation.	- Prepared to take other risks - Prepared to take shortcuts - Must take risks to complete a task - Do a task in a better way if the procedure is inefficient
Attitude (A1–A2 [a]) [30,50,51]	Construction workers have a higher intention of safety violations if they are not receptive to following safety rules and procedures.	H2: Attitude has a positive impact on intention.	- Good to follow rules and procedures - Worthwhile to follow rules and procedures

Table 1. *Cont.*

Construct	Description	Hypothesis	Short Description of Measurement Items
Subjective and descriptive norms (N1–N6 [a]) [30,50,51]	Construction workers would have a higher intention when their coworkers and supervisors are less determined for safety and are seen as not consistently adhering to safety rules and procedures.	H3: Norms have a positive impact on intention.	Subjective norms - Supervisors recognise unavoidable deviations from rules - Coworkers and workgroups recognise unavoidable deviations from rules Descriptive norms - Supervisors force individuals to violate rules - Supervisors do not take action against those who break rules - Coworkers and workgroups coerce others into rule-breaking - Coworkers and workgroups use varying standards
PBC (P1–P3 [a]) [30,50,51]	Evaluates the workers' view on their ability and resources accessible for adhering to safety rules and procedures.	H4: PBC has a positive impact on intention.	- Working conditions stop me from working to the rules - Find better ways of doing my job - Can finish the job quicker - Lack of adequate resources leads to violations of rules
Perceived quality of safety rules and procedures (Q1–Q12 [a]) [30]	When workers think that the safety rules and procedures are of higher quality, they have a more negative attitude, norms, and PBC on safety violations.	H5a/H5b/H5c: Perceived quality of safety rules and procedures has a negative effect on attitude (H5a)/norms (H5b)/perceived behavioural control (H5c) of safety violations.	- Rules do not outline the most effective method of working - Timelines provide inadequate time to finish the task - Rules would make jobs less efficient - Rules are hard to apply - Rules frequently refer to other rules - Rules are factually incorrect - Restrictive operating limits stated in rules - No need to follow rules to do the job safely - Rules only protect management - No efficient monitoring procedures - Working to the rules hinders skills - Have rules that are irrelevant to tasks
HRO (H1–H9 [a])[39]	Construction workers have a more negative attitude, norms, and PBC of safety violations when they perceive that their organisations have a higher level of HRO characteristics.	H6a/H6b/H6c: HRO has a negative effect on attitude (H6a)/norms (H6b)/PBC (H6c) of safety violations.	- Understand individuals' abilities and strengths well - Discuss errors made and the lessons that were gained from them - Discuss and know who has specialised skills and knowledge - Discuss alternatives for our everyday work activities - Discuss with coworkers about emerging problems - Make use of the colleagues' unique skills to resolve a problem - Spend time identifying activities to avoid going wrong - Discuss how we could have prevented errors from happening - Rapidly pool our collective expertise to resolve a crisis

Table 1. *Cont.*

Construct	Description	Hypothesis	Short Description of Measurement Items
Safety compliance (SC1–SC4 [b]) [52]	Dependent variable	Refer above	- Work in a safe manner - Use necessary safety equipment - Use the correct safety procedures - Ensure the highest safety standard
Safety violations (SV1–SV3 [b]) [49]	Dependent variable	Refer above	- Whether approved procedures are followed - Perform a familiar task by referring to the approved documents - "Bend" formal procedures to complete a task on time
Safety participation (SP1–SP3 [b]) [52]	Dependent variable	Refer above	- Extra effort to improve workplace safety - Help my coworkers under dangerous conditions - Voluntarily carry out tasks to improve safety

[a] The scale of the measure is as follows: (1) strongly disagree; (2) disagree; (3) sometimes disagree; (4) neither disagree nor agree; (5) sometimes agree; (6) agree; (7) strongly agree.
[b] The scale of the measure is as follows: (1) never; (2) rarely; (3) occasionally; (4) sometimes; (5) frequently; (6) usually; (7) always.

2.3. Data Collection Method

The questionnaire survey took 20–30 min to complete. The seven-point Likert scale of the measurement items was used, which is in line with the recommendation of Ajzen [50] and Francis et al. [51], and previous TPB studies. Twenty-three nos. of the pilot survey were conducted. Focus group interviews were conducted by Zoom to collect feedback from local practitioners. They provided several minor comments to refine the questionnaire.

First, job nature was revised for respondents, providing a better indication of their background: (1) developer, (2) government, (3) main contractor, (4) sub-contractor, (5) consultant, (6) others: quasi-government, public utilities. The options of working level were also updated to be more specific for data analysis: (1) management, (2) project manager, (3) architect, (4) engineer, (5) surveyor, (6) foreman and supervisor, (7) worker. In addition, the scale measuring the respondents' attitude "Strictly following rules and procedures is good/bad" was revised to exclude the negative covariance, thereby reducing the difficulty in understanding the range of answers. Demographic variables included gender, age, race, education, religiosity, marital status, living with children, job nature, working level, and working location (adapted from Barrientos-Gutierrez et al. [53]).

The main survey invited the participation of various construction companies. A large construction company allowed the researcher to visit its safety centre to distribute the hardcopy questionnaire for collecting the self-reported data. In addition to the mandatory safety training course required by the government, its workers need to attend an additional training course to understand house rules and enhance their safety knowledge. They also need to participate in the refresher course every three years. Other construction companies allow the researcher to visit the project sites and distribute the hardcopy questionnaire during rest breaks and lunchtime. The research purpose, anonymity and confidentiality were clearly explained to the participants before they started filling out the questionnaire. To reduce social desirability, the researcher emphasised the independent nature of this research, i.e., for academic research purposes only. The staff of the participating construction companies also stayed away from the construction workers throughout the whole process of filling out the questionnaire.

Random sampling was adopted to obtain the data. The population determines the required sample size. Based on the government's figure for people employed in the construction industry (351,600) in 2024 [54], the sample size for the population over 100,000 for achieving ±5%, ±7% and ±10% precision levels, where the confidence level is 95% and P = 0.5, would be 400, 204 and 100, respectively. In addition, there should be at least 200 participants to yield accurate parameter estimates for the Structural Equation Modelling (SEM) techniques to be adopted in the data analysis (Marsh et al., 1988, as cited in [55], p. 43). Based on the different suggestions, the sample size is targeted at 300.

In total, 1263 questionnaires were issued, and 795 nos. of questionnaires were received. The return rate was 63%. Data screening was conducted to exclude 244 incomplete responses, and 46 data components were then removed due to low standard deviation, as they reflect responses with the same answer throughout the whole questionnaire. Respondents who worked as workers and foremen and supervisors were included only as their characteristics, working environment, and safety behaviours would be unique, as revealed from the literature review. Based on data screening, a total of 365 valid and complete responses were adopted for the analysis. The valid response rate was 46%.

After analysing the quantitative results, 37 semi-structured interviews were conducted, each lasting 20–30 min. Several open-ended questions were asked, which allowed respondents to share their opinions on relevant issues and ideas freely. The respondents were first invited to introduce themselves, including their trade, work experience, and how

they work with others. Options were provided for them to facilitate brainstorming and guide them with a framework for sharing their opinions on safety performance: (a) elder workers are better; (b) young workers are better; (c) not much difference; and (d) unable to tell. They were then asked to comment on the questionnaire results. After the respondents were encouraged to speak out, the researcher invited them to elaborate further on their opinions, provide reasons with examples.

The focus is on several major awareness perspectives that have been raised in recent years. First, the issue of an ageing workforce highlights the importance of investigating various aspects of workers, including their types, work styles, and why they work in such a way. Second, the current nature and methods of safety promotion, and what factors affect safety compliance, could be meaningful for understanding the problems of violations. All quotes were translated as the workers stated them in non-standard English. For the qualitative data analysis, content analysis for interview scripts was conducted by using NVivo 15.

3. Results

3.1. Quantitative Results and Analysis

Nearly half of the respondents (49.3%) came from main contractors, followed by 40.9% of subcontractors. The working location of the majority (94.6%) is sites, and the remaining 5.4% worked in site offices. The gender proportion (male 93.9%; female 6.1%) was in line with the population in the Hong Kong construction industry (male 87.5%; female 12.5%) [54] and the male-dominated condition in other countries. More than half of them (54.0%) were 25–34 and 35–44 years old. 35.5% of participants were elder construction practitioners, aged between 45 and 54 and 55 and over. Only 10.5% were the youngest (18–24 years old). The respondents were mainly graduates from secondary school (53.9%) and higher forms of secondary school (26.2%). There were around two-thirds of the respondents (69.0%) who are married, with 64.8% living with their children. The major nationalities were Chinese (84.3%), together with Nepalese (12.4%).

Statistical Package for the Social Sciences (SPSS) 30 was utilised to compute reliability and conduct factor analysis, whereas SEM was carried out through Analysis of Moment Structures (AMOS). The reliability and validity of the questionnaire were assessed. Reliability is the level that the questionnaire produces stable and consistent results where validity reflects the level of what is purported to measure [56]. Cronbach's alpha, of all the items, is higher than 0.7 (except safety participation (SP), 0.689), reflecting acceptable reliability (Nunnally, 1978, as cited in [57], p. 709). SP was therefore removed from additional analyses.

Factor analysis facilitates an understanding of the organisation of variables [57]. Principal components analysis (PCA) was used for each construct to reduce the size of a set of variables [58]. The factor loadings of measurement items Q2 (insufficient time to comply) and P1 (conditions at the workplace) were less than the cut-off value of 0.4; therefore, they were excluded to improve the model fit. The PCA results suggested extracting three components from perceived quality. The three main components were efficiency (Quality 1), effectiveness (Quality 2), and relevance of rules (Quality 3).

SEM was then carried out for both the measurement model, i.e., latent variables (factors), and the structural model, i.e., relationships among different factors [59]. Although SEM can analyse different relationships among latent and observed variables simultaneously [55], Anderson and Gerbing [60] recommend analysing each construct first, followed by the overall measurement model and then the structural model. Global fit measures are used to assess the model fit with the sample data. Model modification is required for individual constructs if the model cannot achieve the acceptable fitness indices [57]. The acceptable fitness indicators are listed below: (1) χ^2/degrees of freedom < 3 (CMIN/DF),

(2) Tucker–Lewis index > 0.80 (TLI), (3) Comparative Fit Index > 0.80 (CFI), (4) Root Mean Squared Error of Approximation is good if <0.05; 0.05 to 0.10 as moderate; >0.10 as bad (RMSEA) [61].

The model fit could be enhanced through two steps: (1) the items with the standard estimate lower than the required 0.50 level were removed, (2) error terms within the same factor were covaried, starting from the largest modification indices [62]. The model modified for each construct and the structural model is summarised in Figure 2. It also presents the outcomes of standardised estimates and model fit indices for the modified structural model. The significance levels ($p \leq 0.001$) of the path estimates were also considered when analysing the results.

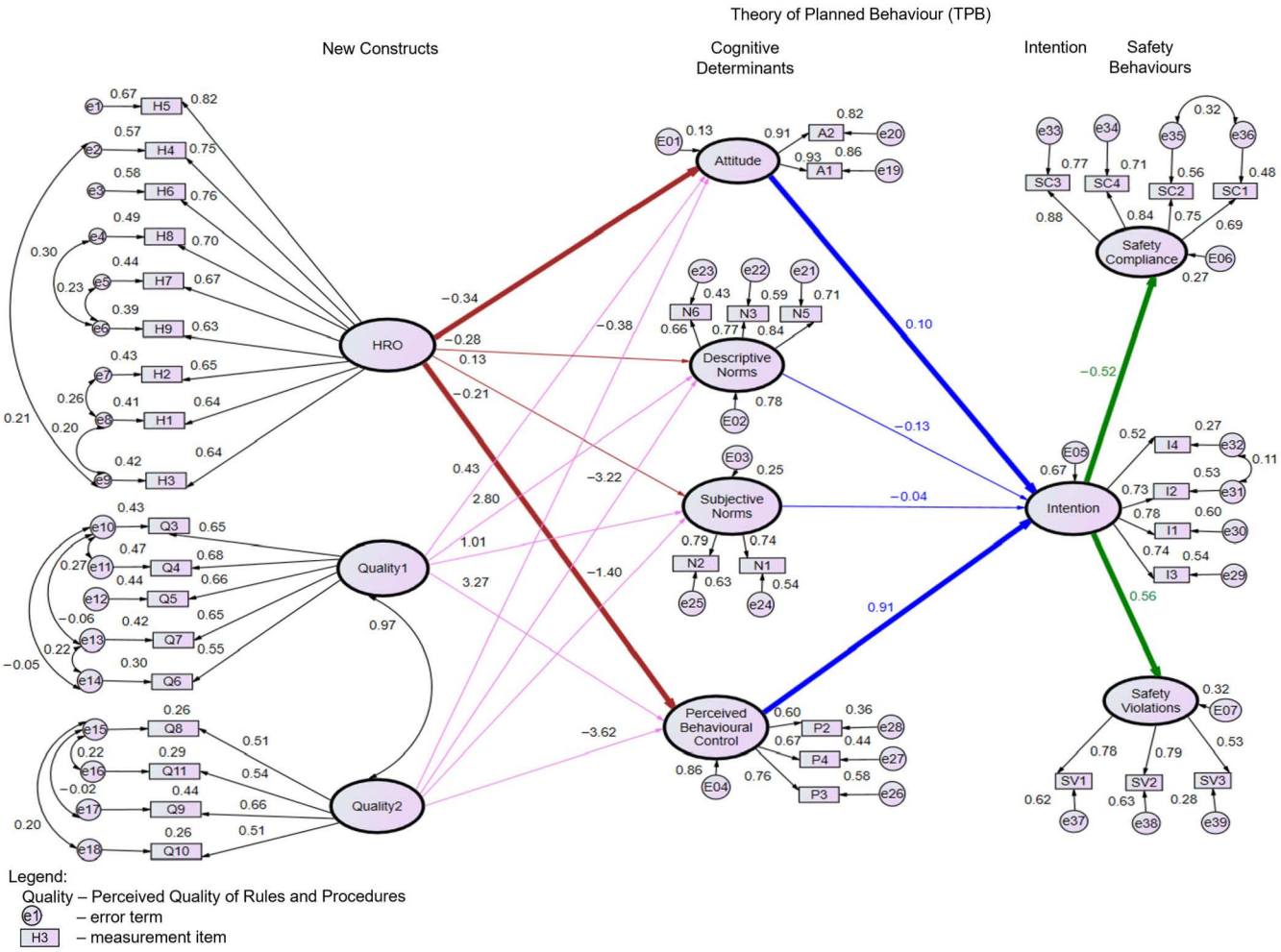

Figure 2. Standardised parameter estimates of modified structural model (Chi-square/df = 2.687, *p*-value = 0.000, TLI = 0.819, CFI = 0.836, RMSEA = 0.068). The confirmed hypotheses are indicated with bold arrows (significance $p \leq 0.001$).

Intention of safety violations was found to significantly impact safety compliance (H1a) and violations (H1b) despite participation (H1c) being excluded for the low internal consistency. Intention had a negative impact on self-reported safety compliance and a positive impact on violations (significance level of the regression weight at 0.001 level). Safety compliance decreased by 0.52, and safety violations increased by 0.56 when intention increased by 1.

Both attitude (H2) and PBC (H4) have a significant positive impact on intention, but the effect of attitude (+0.10) was much weaker than PBC (+0.91). Nevertheless, H3 (subjec-

tive and descriptive norms) was refuted since insignificant negative impacts on the intention of safety violations were found.

The significant negative statistical effects of perceived quality on the three cognitive determinants were rejected, as Quality 2 and Quality 1 had significant negative and positive predictions on descriptive and subjective norms, and PBC at the same time. The refutation of the impact of Quality 1 is explained in Section 4.

These results are in line with others that HRO has significant negative statistical effects on attitude and PBC. H6a and H6c were confirmed at regression weights of −0.34 and −0.21, respectively. HRO showed considerable positive predictions on subjective norms and negative forecasts on descriptive norms, therefore rejecting H6b. The refutation of the impact of HRO on subjective norms is explained in Section 4.

3.2. Qualitative Results and Analysis

3.2.1. Data Collection and Analysis

A word frequency query was conducted to provide an overview of the issues before analysing the interview scripts in detail. The criteria of the query were to display the top 100 words with a minimum word length of 3. The words were grouped with the same stem, such as require, required, requirement, requirements, and requires. The words were listed in descending order by length, count, weighted percentage, and similar words. Linking words such as main, since, may, and one were included in the stop-word-list to elicit a more meaningful picture. The top 15 words were rules, site, training, company, contractors, teaching, awareness, progress, dangers, foremen, supervisors, experience, subcontractors, accidents, and remind.

The interview scripts were first organised in different formats to distinguish the questions and answers. The first stage of "noding"—autocoding was conducted by the software based on the questions. The scripts were then read through for manual coding to classify them into smaller subtopics and groupings. The data were further imported into NVivo 15 for conducting crosstab tests on each question, aiming to identify distinguishing patterns in the findings, similarities, and differences among all respondents and each group of respondents.

3.2.2. Sih-Fus (師傅) Versus Young Workers on Safety

In Hong Kong, individuals refer to seasoned workers with greater experience as Sih-Fus (師傅). Nevertheless, there is no clear-cut definition for Sih-Fus (師傅). It serves merely as a general term, and people often rely on work experience for categorisation. In order to establish a rapport with the respondents, workers who have been working for more than ten years were called Sih-Fus (師傅) through the interviews. Those Sih-Fus (師傅) generally accepted this title, and young workers did not have any adverse comments on this classification.

The interviews revealed deep insight into Sih-Fus (師傅) and young workers' self-perceived safety performance. Their unique characteristics can be outlined based on their skills and adaptability. Interestingly, the shortcomings of Sih-Fus (師傅) can be viewed as the advantages of young workers. For example, Sih-Fus (師傅) possess greater experience, allowing them to identify hazards on sites better, while they might also exhibit a level of over-confidence in their own capabilities.

Young workers think that Sih-Fus (師傅) deserve respect for being a "master" for young workers since they have better workmanship and much experience in safety and all aspects of their work. However, most Sih-Fus (師傅) do not acknowledge such responsibility. In reality, they focus on productivity. Their low safety engagement in training young workers may be explained by their perceived age similarity with others [63]. Sih-

Fus (師傅) may not develop a close relationship with young workers easily due to their generation gap. This phenomenon may result from the daily wage system and high mobility of Hong Kong construction industry workers.

3.2.3. Who to Promote Safety?

Regarding who is important in promoting safety, a number of workers recognised the importance of all stakeholders, including themselves. Some middle managers suggested that the management of construction companies has started to recognise the importance of safety engagement. Although managers and supervisors expect changes in workers' attitudes, they do not engage effectively in promoting the desired changes [64]. In addition, there is low safety engagement of construction workers.

The findings can be explained by the top-down approach suggested by Rasmussen [65] that the construction industry comprises multiple levels. Regarding policy establishment, the rules and procedures are set by the top level, i.e., the head office. Lower levels then execute the rules and procedures. Sih-Fus of subcontractors usually can only follow those rules. Bottom-up mechanisms are unavailable for reflecting their views and communicating their difficulties with upper levels. Eventually, they have little communication about safety with their coworkers and supervisors. Most of them think that they only have to be compliant. The interviewees also recognised that more safety training opportunities should be provided at construction sites to address safety issues. The current training content does not consider the uniqueness of every work trade and dynamic changes at sites.

3.2.4. Factors Affecting Safety Compliance

The finding of PBC being the most significant factor affecting construction workers' intention on safety compliance was reinforced by the interviews that over half of the respondents highlighted work progress and working environment as the key factors affecting safety compliance. Sih-Fus (師傅) trusted that they were knowledgeable. However, they were pressured to finish the work, so they decided to work without complying with the safety rules. Interestingly, this view can be supported by the findings that lesions occur more frequently in the later stages of civil construction projects of the Brazilian Amazon [66].

The working environment can also be interpreted as an element of PBC. First, it relates to the physical working environment in which sufficient space is required to carry out the safety measures. Second, the safety standard varies among different main contractors. The standard would be higher for government jobs. Third, monitoring levels affect safety compliance. The second and third items are in line with the technical and management or government causes identified in Nigerian construction sites (Ebekozien et al. [67]).

The significant effect of attitude on intention was also found, although its impact was much weaker when compared to PBC. Nevertheless, over one-third of the respondents reaffirmed this finding. When compared to the term "attitude", "self-awareness" was much more frequently mentioned by many respondents. Self-awareness reflects the concept of mindfulness in HRO. Mindfulness refers to HRO having "a mental orientation and a rich awareness of discriminatory detail, i.e., when people act, they are aware of context, of ways in that details differ, and of deviations from their expectations" [39] (pp. 88 and 32).

Surprisingly, some of them admitted that they have low safety awareness. They would be more aware of safety if they and other workers had accidents before or were afraid of being punished. Frontline workers generally have lower safety awareness. They may only concentrate on their own task. For instance, the workers who wash site vehicles may ignore lifting work. Self-awareness depends on workers' perception of whether safety or "earning money" is more important. The relevant importance of their own lives

may be related to their personality. Using Personal Protective Equipment as an example, workers are the ones who choose to use it or not. It may be difficult to ensure that they use it. If workers have high safety awareness, they will review the environment and work only if it is safe. In their opinions, their self-awareness is affected by other factors, such as the mindset of "catch up on progress", inspection (punishment) and monetary reward.

Some Sih-Fus (師傅) and young workers suggested that self-awareness, which refers to safety and communication awareness, is more important than norms since safety compliance depends on whether you are willing to be injured yourself. Nevertheless, some respondents suggested that norms are still important. Norms represent the overall atmosphere in the working environment, and it is created by people working there. The respondents suggested that Sih-Fus (師傅) could serve as a negative example for young workers. For instance, they may follow the instructions directly. If Sih-Fus (師傅) ask them to cut corners to catch up on the progress, they may simply ignore the safety rules.

In line with the research model, the quality of safety rules and procedures was explained by several respondents as a meso factor. The objectives of the safety rules and procedures seem unclear to some Sih-Fus (師傅). Both Sih-Fus (師傅) and young workers shared their difficulties in complying with different sets of safety rules established by different main contractors and clients. The intention in safety compliance is adversely affected by inconsistent safety standards of construction companies. The inconsistent safety standards would adversely affect the construction workers' self-awareness in return.

Respondents also shared a number of macro factors affecting construction workers' safety compliance. The institutional contributors consist of (1) subcontracting and salary structures and (2) competitive bidding. While these broader elements may not have a direct impact on safety compliance, they can have a detrimental influence on the aforementioned meso and micro factors. The increased mobility stemming from the use of the subcontracting system negatively impacts the retention of safety knowledge and the motivation to educate young workers.

Aside from the daily wage, the Cau-Ga (炒家) system is frequently employed in finishing works and scaffolding. Its structure resembles subcontracting, albeit on a smaller level. Subcontractors "subcontract" portion of the work, often divided by floor or area, to Cau-Gas (炒家), which consists of gangs of skilled Sih-Fus (師傅). Notably, these Sih-Fus (師傅) typically work on a daily basis. Simultaneously, they complete urgent tasks for an additional incentive. This bonus system is prevalent for projects with tight timelines. As a result, Cau-Gas (炒家) tend to prioritise productivity, leading them to limit interactions with less-experienced workers. The widespread use of Cau-Gas (炒家) in construction projects highlights the emphasis placed on site progress. Additionally, the respondents indicated that all parties involved in construction projects should be involved in safety from the beginning, encompassing the procurement approach (competitive tendering) to the overall safety culture within the industry.

4. Discussion

In the research model, H1a and H1b were confirmed. Mediocre coefficients were discovered that aligned with the TPB, indicating that intention is the most direct influence on human actions. Construction workers play a crucial role in their own safety behaviours since they are in control of their actions. While earlier research presents varied perspectives on the human influence in the causes of accidents, this finding emphasises the significance of workers in relation to safety adherence and infractions, underlining the importance of human factors.

There are three proximal factors and two distal factors affecting workers' intention of safety violations in this adapted TPB model. The elements influencing workers' adherence

to safety rules can be categorised into micro, meso, to macro factors [68]. The closer factors can be considered as micro factors, while the more distant factors are seen as meso factors. These may stem from the institutional contributors identified by the interviewees that can be viewed as macro factors. The underlying institutional issues contributing to the present situation of Hong Kong construction workers' safety violations can be explained in terms of the "socio-technical systems" view. Considering the definition by Noy et al. [12] in this context, the workers' safety compliance is shaped by the interactive influences of work relations and technology (i.e., social and technical subsystems). Therefore, the research model provides a framework for examining safety violations, but the existence of other possible factors and their interactions should also be considered.

Within the three cognitive factors identified in the TPB, PBC emerged as the most significant influence on intention. The confirmed H4 supported the development of the TPB from the TRA with PBC incorporated. Behaviours are not always under people's complete control, i.e., safety violations in this research. Ability pertains to the craftsmanship and experience of the workers, specifically regarding how they can perform tasks while adhering to safety rules or not. Additionally, the perceived capability would also be influenced by the external factors. The significance of PBC aligns with Peng and Chan [27], who suggest that workers tend to work safely when they believe they have such competence. However, the findings of attitude and norms are contradictory with Peng and Chan [27], which can be explained by the relevance and importance of these two constructs.

Regarding attitude, H2 was confirmed but the influence of attitude was considerably less than that of PBC. Attitude refers to how workers value safety, i.e., whether they would place safety over other concerns, such as site progress. Many participants mentioned that attitude correlates with self-awareness. Workers who possess a greater awareness of safety are more inclined to adhere to safety rules. Self-awareness of individual workers reflects how well construction companies apply the concept of mindfulness in HRO.

The original TPB only examines the subjective norms on intention and recent studies further develop the theory by including descriptive norms. H3 was refuted as both subjective and descriptive norms insignificantly and negatively impacted intention. Although the finding seems different from other studies which emphasise the roles of supervisor and peer support in different aspects, such as mental health of the construction workers in Australia [69], the results can be interpreted through the concept of identity discussed by Choi and Lee [70]. When workers do not feel a sense of belonging to their reference group, i.e., their coworkers and supervisors, group norms do not affect safety practices. This finding aligns with the significant effect of relational identification (i.e., workers' identification with their supervisors) on safety behaviour in the Pakistan construction industry, where safety norms are contingent on relational identification [71]. Safety engagement with construction workers and their safety voice is generally at a low level in Hong Kong. Therefore, it is sensible to suggest that such relational identification does not commonly exist in construction projects, so norms do not demonstrate the significant positive impacts as hypothesised.

In addition, the significant impacts of attitude on intention imply that their self-awareness (own attitude) would be more important than coworkers and supervisors' behaviour and pressure from them. Norms may indirectly affect intention via PBC and attitude. Since the behaviours and pressure on safety violations may not be obvious, the mentality of "catch up on progress" may result in brainwashed workers due to their coworkers and supervisors' daily behaviours and social pressure.

H6a and H6c were confirmed. HRO affects the PBC and attitude significantly. This result pinpoints HRO as affecting close factors and, as a result, the intention of safety compliance. High reliability organisations refer to the capability of construction companies to

keep their sites operating with minimal accident occurrences. To reach this goal, construction companies need to embody the five principles related to foreseeing and managing unforeseen events. The findings align with the proposition in Rowlinson et al. [4] of cultivating some new initiatives to improve the maturity of the Hong Kong construction organisations. H6b was refuted. Nevertheless, a significant negative impact was found in HRO on descriptive norms. This may be explained by the rationale of HRO that it does not refer to strict safety compliance but requires a sense of reflectiveness for ongoing improvement on safety rules and procedures.

Instead of strict compliance, HROs can be viewed as the "Model 2" of safety rules management which blame culture, indicating that it should not be maintained for safety violations, and the translation process; adaptation to any situation is required [31]. Heedfulness of the surrounding environment is important for managing uncontrollable risks in HROs, and such heedfulness may cause violations of safety rules [36]. As suggested by Gudela and Weichbrodt [72], in addition to a mindful culture, construction companies should carefully assess their safety rules and procedures since they affect the stability and flexibility of organisational processes for being HROs successfully. In Hong Kong, there are prescriptive and performance-based safety legislation that contractors need to comply with and employ proactive safety management approaches to satisfy different stakeholders' requirements simultaneously [73]. The dichotomy does not fit well for HRO.

Regarding perceived quality of safety rules and procedures, H5 was refuted. Factor Q2 and Q1 have contradictory results; only the former showed a significant impact as hypothesised. Although the results were not uniform, the interviewee feedback provided insight into the existing situation. Safety rules and procedures may be sufficient for professional management, but they seem inadequate for the workers because of the subcontracting system. The application of the rules should be tailored to the circumstances and abilities of the users [31]. Nevertheless, the head office/management establishes the safety requirements, and then the site offices need to implement them in Hong Kong. The construction workers are generally not engaged in safety management.

In addition to improving current safety trainings that adopt classroom and traditional paper-based examination, the interviews support the proposition of Shen et al. [74] that workers, in particular Sih-Fus (師傅), who are likely to be affected by deep-rooted habits, should be continually reminded about work safety, including those who work for construction companies with a positive safety climate. Recent studies have advocated for the adoption of various technologies to address the weaknesses of traditional approaches, as the effectiveness of the mandatory safety training course designed by the government is considered low. Virtual Reality (VR)-based instructional methods enhance learning roles from passive to active, increasing involvement and further enhancing awareness, and enabling individuals to identify and respond to hazards quickly [75]. Active training methods can be combined, such as discussion, demonstration, simulation, gamification, Augmented Reality (AR) and VR to achieve the best training results [76]. The latest Artificial Intelligence (AI) agent, utilising ChatGPT, can be further incorporated to enhance safety training by creating a customised learning experience for each trainee [77].

In line with the distinctive features between young workers and Sih-Fus (師傅) highlighted by the interviewees, different learning styles should be considered in safety training. Despite VR safety training generally improving hazard identification performance better than traditional approaches, only active, intuitive, and sequential learners can achieve better performance. In contrast, reflective, verbal, and global learners surprisingly show greater improvement in traditional safety training [78]. However, the limitations of technology should not be overlooked. In addition to the high initial cost, technical challenges

(such as integration, data privacy, and security), and applicability across different project scales, workers may be resistant and difficult to adapt to new technology [79].

Weaknesses in safety management should also be addressed. For instance, using retrospective data, e.g., accident rate, for assessing safety performance is passive. An active approach, such as behavioural monitoring of workers' actions for providing immediate feedback, would be desirable. Smart Personal Protective Equipment (PPE), featuring advanced sensors and communication systems embedded in helmets, as well as sensor-equipped vests, enables real-time hazard monitoring [80]. Many other studies also suggest the use of technology in construction safety management throughout the whole project lifecycle. Building Information Modelling (BIM) can be developed towards automation hazard identification and assessment [81] whereas digital twin technology can be applied in five major aspects: (1) real-time monitoring and early warning, (2) risk prediction and assessment, (3) accident simulation and emergency response, (4) decision support, (5) training and education [82]. The interventions will be effective only if the safety management system is well developed [61].

Although the interview respondents did not express any particular concerns about specific types of work or safety violations, findings from other studies can be referred to. For high-rise building construction projects in Malaysia, the most severe violation is the lack of fire protection, while the most frequent safety rule violations include the absence of risk, near-miss accident reporting, and procedures during maintenance activities [83]. In Kuwait, scaffolds and fall protection are the two most significant safety violations, accounting for 43% of all violations in the frequent analysis and leading to two fatalities [84]. This finding aligns with the major causes of fatal accidents in Hong Kong, where five scaffold accidents and eight fall protection accidents occurred in 2024 [85].

5. Conclusions

This research provides a comprehensive investigation into safety violations among construction workers in Hong Kong, with a particular focus on the socio-cultural dynamics and institutional factors that influence behaviour. Through a questionnaire survey and in-depth interviews, the study identifies unique roles and behavioural patterns of Sih-Fus (師傅) and Cau-Gas (炒家), revealing how these identities contribute to persistent safety issues on construction sites.

By validating the TPB framework in a construction setting, we linked workers' attitudes, perceived behavioural control (PBC), and intentions to safety compliance with an innovative application of the HRO measurement tool to construction organisations. The findings support socio-technical system thinking, which demonstrates that workers' safety violations interact with their network of work relationships and the work process and techniques [12].

Although the research focuses on construction workers, all stakeholders should be responsible for the workers' safety behaviours. This is the essence of HRO that the whole construction organisation should be mindful. It also reframes safety compliance as an institutional issue rather than an individual one. Thus, this research argues for institutional collaboration to alleviate pressure and improve safety outcomes. The institutional contributors reveal the reality that the government, developers, consultants, main contractors and subcontractors should collaborate. For instance, the government can provide subsidies to subcontractors for providing training opportunities and subsidise the income of their workers attending training courses. This research reveals that safety violations are systemic, which necessitates multi-stakeholder engagement.

This research provides policymakers with actionable insights to design targeted interventions based on workers' PBC and attitudes, as established in the findings: workers'

PBC and attitudes affect their intention, which in turn improves their safety compliance. All stakeholders are responsible for enhancing site progress and the environment. For example, clients and consultants should establish a realistic schedule, reduce design changes, and associate abortive works with later construction stages to alleviate pressure on work progress. Meanwhile, main contractors should ensure they have adequate working space, effective planning and resourcing to smooth the execution of their projects.

Training should be customised to meet the unique characteristics demonstrated by Sih-Fus (師傅) and by young workers. For instance, the training for young workers should concentrate on improving their understanding of the reasoning and importance behind safety rules and procedures, while Sih-Fus (師傅) should be made aware of potential hazards and the significance of being self-aware. Existing habits of Sih-Fus (師傅) should be changed and new habits (i.e., good practice) should be developed in the long term since habits represent Sih-Fus' (師傅) beliefs of what behaviours are correct.

Limitations and Future Research Directions

It is essential to recognise that each research study has its limitations. In this study, the construction workers themselves reported the quantitative results regarding safety compliance and violations. Proper informed consent procedures have been followed. Focus group interviews with local practitioners were carried out to assess item comprehension and measurement validity. A data screening process was carried out to guarantee the quality of data analysis. For qualitative results, the researcher may have bias during organising and analysing the data, so content analysis was conducted more systematically by using NVivo 15. The comprehensive steps adopted for analysing the qualitative data are illustrated in Section 3.2.1 in detail.

This study focuses on the mentality of frontline construction workers. Future research could explore and measure the effectiveness of specific safety training programmes, interventions, and technologies applied in construction sites. Future research could further investigate scaffolds and fall protection violations, which are the two key types of violations identified in various locations. Given the intricate nature of safety violations, it is recommended to conduct an ethnographic study to observe the social interactions and behaviours of construction workers. Additionally, various factors identified during the interviews, along with the results related to safety behaviours such as injury rate and absenteeism, can be integrated into the research model to offer a more comprehensive understanding of safety behaviours. If more time were available, a longitudinal study could have been carried out to assess how safety behaviours change and the influence of different factors over time. The interviewees strongly emphasised the issue of the workers' low safety engagement. The construct of safety engagement can also be examined to reveal different perspectives of safety behaviours in future research.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
AMOS	Analysis of a Moment Structures
AR	Augmented Reality
BIM	Building Information Modelling
CFI	Comparative Fit Index
CMIN/DF	χ2/Degrees of Freedom
HRO	High Reliability Organising
MI	Modification Indices
PBC	Perceived Behavioural Control
PCA	Principal Components Analysis
PPE	Personal Protective Equipment
RMSEA	Root Mean Squared Error of Approximation
SEM	Structural Equation Modelling
SPSS	Statistical Package of the Social Sciences
TLI	Tucker–Lewis Index
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
VR	Virtual Reality

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