Safety Science 181 (2025) 106703

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

A web-based safety management platform to enhance safety for Chinese migrant construction workers

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ARTICLE INFO

Keywords:
Migrant construction workers
Safety platform
Prototype

ABSTRACT

Over the past decade, existing research has investigated various solutions to enhance safety management on construction sites. Among the many solutions, developing a web-based safety platform has increasingly become a key element in safety improvement strategies. International research shows that safety management platforms improve migrant workers' safety, but evidence for such interventions in New Zealand, especially for Chinese migrant construction workers, remains limited. This study built a web prototype catering to Chinese migrant construction workers in New Zealand. The data collection method was semi-structured interviews, and the effectiveness of the novel web prototype was validated based on respondents' feedback. Results show that this safety web prototype can effectively improve the safety knowledge and safety awareness of Chinese migrant construction workers by providing local safety policies and conducting multi-frequency long-term safety training tests. The incentive function in this web prototype can motivate Chinese migrant construction workers to use this application and enhance their safety compliance. The limitations of this research include geographical restrictions and a small sample size to evaluate the effectiveness of the prototype. Future research should incorporate a larger, cross-sectional sample to assess the effectiveness of web-based safety awareness solutions, enabling more generalizable conclusions for construction workers of diverse nationalities and regions.

1. Introduction

1.1. Current background in the construction industry

The construction industry is globally recognized as a high-risk industry due to the uncertainty in the safety management of construction sites (Al Mhdawi et al., 2020, Buckley et al., 2016). In addition to the attribute of high risk, construction is also a labour-intensive industry (Ng and Tang, 2010). Migrant workers from different countries have gradually become a vital resource of labour in the construction industry (Hargreaves et al., 2019). Numerous studies demonstrated that migrant workers are exposed to higher safety injury risks and encounter more challenges in safeguarding their safety rights compared with native workers in the construction industry (Ibarra-Mejía et al., 2021, Fernández-Esquer et al., 2020, Vignoli et al., 2021). For instance, migrant construction workers have a higher risk of injury due to factors such as language barriers, insufficient safety training, and discrimination (Bust et al., 2008, Guan et al., 2024). Due to insufficient knowledge of local safety policies or incomplete labour protection policies, migrant construction workers may be forced to accept high-risk and high-intensity work to avoid potential consequences of unemployment and repatriation (Ibarra-Mejía et al., 2021, Massimiliano et al., 2017, Shepherd et al., 2021). A diverse range of solutions have been suggested to enhance the health and safety of migrant construction workers, aiming to mitigate safety risks and minimize accident hazards at construction sites. For example, audio, video, and pictorial aids have been used to increase migrant construction workers' awareness of safety regulations (Díaz Fuentes et al., 2016, Lara et al., 2021). Employ bilingual individuals in roles such as forepersons, chief engineers, or project managers to alleviate incidents stemming from language barriers among migrant construction workers (Oswald et al., 2019). With the continuous development of digital and networking technologies, web-based safety management platforms are recognised as effective strategies for risk management in the AEC (Architecture, Engineering and Construction)

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https://doi.org/10.1016/j.ssci.2024.106703
Received 28 April 2024; Received in revised form 15 October 2024; Accepted 17 October 2024
Available online 24 October 2024

industry (Zou et al., 2017).

1.2. Literature review for web-based safety management platforms

The web-based safety management platform refers to a safety management system based on digital and network technologies (Wang and Chen, 2024). As construction projects become increasingly complex, the use of web-based safety management platform tools that streamline communication, monitoring, and management has significantly decreased the on-site risks and improved safety outcomes (Zou et al., 2017). The web-based safety management platform can contribute to improving both safety and management efficiency of construction projects through various platform models such as safety training platform (Shayesteh et al., 2023), safety warning mechanism (Liu and Tian, 2019), safety risk management (Li et al., 2018). These platform applications facilitate real-time data sharing (Park et al., 2017), the improvement of the effectiveness of safety training (Bao et al., 2022), and the tracking of compliance with safety regulations, leading to more proactive measures in accident prevention. The literature shows that most existing studies have achieved the goal of improving site safety management in actual construction projects by developing the concept or prototype of safety management platforms (Zou et al., 2017). These prototypes frequently incorporate visualization technologies, such as Virtual Reality (VR) and Building Information Modeling (BIM), to enhance communication, provide safety training, and enable real-time supervision of construction teams.

The results of the literature review indicate that the web-based safety management platforms discussed in existing studies primarily focus on serving the “construction team” or “construction management” in a broad sense, lacking tailored solutions for migrant construction workers. Moreover, these have been primarily conducted in international settings with limited research in New Zealand related to Chinese migrant construction workers. Unlike native workers, migrant workers are more vulnerable to safety incidents in the construction industry due to factors such as language barriers, discrimination, limited access to safety regulations education, and insufficient safety training (Guan et al., 2024). In addition, existing literature on web-based safety management platforms primarily focuses on improving the safety performance of migrant construction workers by enhancing safety training. For instance, Vignoli et al., (2021) developed an online interactive platform featuring a comprehensive safety training package that addresses the challenges posed by one of the most multicultural and multilingual work environments, specifically tailored for migrant workers in the construction sector. However, research on a comprehensive safety management program for migrant construction workers still necessitates substantial data support and in-depth quantitative analysis to further validate and refine these applications (Rodriguez et al., 2018, Vignoli et al., 2021).

1.3. Sample groups

This study utilized Chinese migrant construction workers as the sample groups to derive generalisable conclusions for improving the health and safety of migrant construction workers. The reasons for selecting this population for the study were as follows. Firstly, the research data mainly originates in Auckland, New Zealand. The construction industry in New Zealand has long faced a skill shortage challenge, and migrant construction workers are a vital labour resource in addressing this challenge (Lobo and Wilkinson, 2008). Chinese migrant workers served as an important part of the migrant workers. With over 10 million emigrants (International Organization For Migration (IOM), 2024), Chinese migrant workers are dispersed in nearly every country worldwide, especially in Australia, Canada, New Zealand, and the United States (Poston et al., 2016). Chinese migrant workers are one of the largest migrant groups in the Auckland construction industry, accounting for 16 % (the maximum rate) of all overseas migrant workers from 2016 to 2018 (Sweet Analytics, 2023). However, there is still a lack of data and research on their health and safety challenges such as population statistics, the number of injury accidents, and fatal rates (Liu and Lu, 2015). This means that as a significant part of the construction workforce in New Zealand, research on health and safety improvement strategies for Chinese migrant construction workers is conducive to enhancing the overall safety standards of the construction industry. Based on the research findings derived from Chinese migrant construction workers, further research can be conducted on health and safety improvement strategies for migrant construction workers of various nationalities in different countries.

1.4. Research aim, gaps, and objectives

Existing literature on web-based safety management platforms lacks targeted analysis of migrant construction workers. This study aims to explore the impact pathways and effectiveness of web-based safety management platforms on improving the health and safety of Chinese migrant construction workers. This study also aims to draw a generalisable conclusion for all migrant workers in the construction industry based on the research results of Chinese migrant construction workers. The following research questions were proposed in this study to fill the research gaps. What special functions should a web-based safety management platform have for migrant construction workers? How does the safety platform improve the health and safety of Chinese migrant construction workers, and is it effective? To address these research questions, two objectives are proposed.

)1. to establish a novel safety web platform prototype and improve the prototype based on the feedback from Chinese migrant construction workers regarding on-site safety management requirements.
)2. to evaluate the effectiveness of a web-based safety management platform in improving the health and safety of Chinese migrant construction workers.

This study contributes to both construction organizations and individuals. For instance, this study fills the research gap in the field of health and safety for migrant construction workers. It also offers an innovative safety management prototype tailored for Chinese migrant workers and construction organizations, promoting practical applications.

2. HYPERLINK “SPS:id::Sec2” Methods

This study created a safety web platform prototype for Chinese migrant construction workers and an effectiveness analysis was conducted based on the examination of user feedback after its utilization. This method, constructing a prototype with specific targeting for collecting data, has been proven to be a best practice strategy by multiple studies such as (Bradbury et al., 2018, Le et al., 2015, Yardley et al., 2015). Semi-structured interviews were conducted to collect feedback from respondents on the effectiveness of the safety web prototype. The method utilized in this study consists of three phases and the flow chart is shown in Fig. 1.

2.1. Phase 1. Recruitment and screening of migrant construction workers

This phase is to invite and screen migrant construction workers to participate in the assessment of the web prototype as interview respondents. The research subjects are Chinese migrant workers who have Chinese Citizenship and have legal work in the construction industry outside of their country of origin. Respondents in the interviews of this study met all the following 3 criteria.

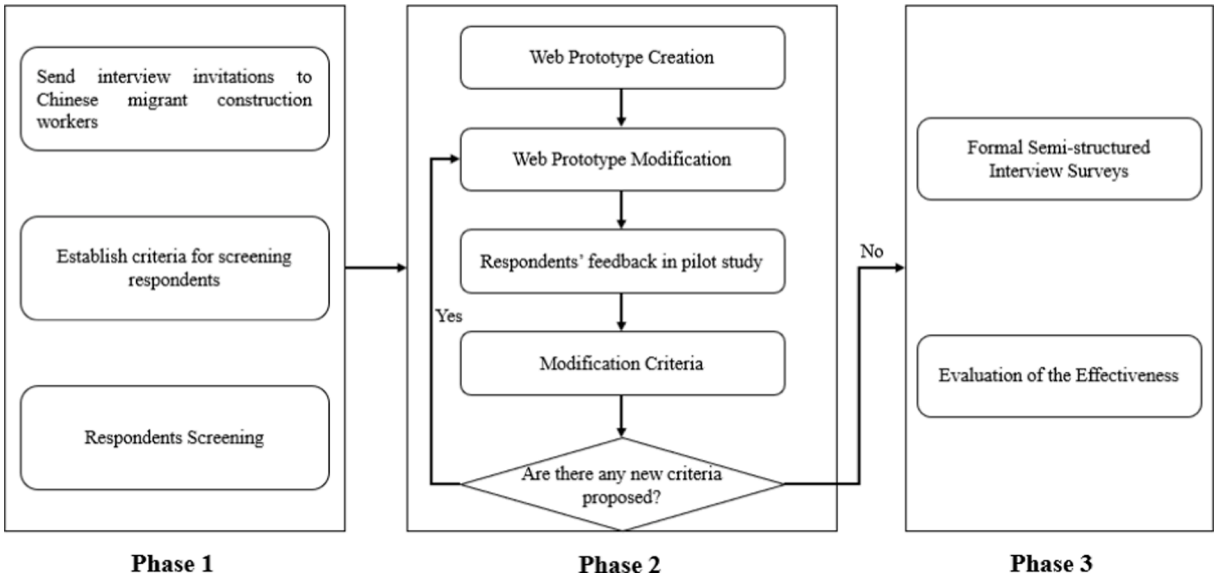


Fig. 1. Method for the construction and implementation of web prototype.

1. The respondent has a valid Chinese passport, including mainland Chinese passports, Hong Kong passports, Macau passports, and Taiwan passports,
2. The respondent has a current contract signed in the New Zealand construction industry,
3. The respondent has a legal visa that allows migrants to participate in construction work.

This study sought assistance from Site Safe in New Zealand to ensure an adequate sample size. Site Safe is a national not-for-profit membership organisation and has played a vital role in creating a positive change in the health and safety culture within the New Zealand construction industry (NZCI) since 1999 (Site Safe, 2023a). Site Safe also provides a comprehensive safety training service and provides safety knowledge and skills training for various types of construction sites to more than 78,000 workers annually (Site Safe, 2023a). Currently, Site Safe boasts a total of 6,315 companies' membership from construction and related industries in New Zealand (Site Safe, 2021). Therefore, based on the construction workers database from Site Safe, interview invitations were distributed to construction workers in NZCI via With the help of Site Safe, a total of 8,337 contacts received the invitation. Chinese migrant construction workers can contact the researchers via email, phone, or WeChat. Before the interview surveys, *this project was evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees*. The Massey University Human Ethics Committee Notification Number is 4000027904.

2.2. Phase 2. Establishment and improvement of the web prototype

The objective of this phase was to construct a web prototype and improve it based on the results from the pilot research. This phase was divided into two steps.

2.2.1. Establishment of the web prototype

With the development of digital technologies, many scholars have created an original platform prototype as a novel approach to conducting in-depth research in their respective fields (Soman et al., 2020, Chen et al., 2019). The web-based safety management platform prototype in this study was created using Wix. Wix is a popular website-building platform with a variety of built-in features to assist users in designing professional websites (Wix, 2023). Wix not only provides users with a user-friendly and intuitive website editor for ease of use but can also create custom services tailored to user requirements and unique characteristics (Wix, 2023). Before establishing the web prototype, this study reviewed the existing web-based safety management platforms used by various construction companies. The features of these web-based safety management platforms are shown in Fig. 2.

It can be seen from Fig. 2 that each web-based safety management platform comprises various features to streamline venue on-site safety management and reduce safety management workload and management hours eventually. Those key features can be categorized into three main aspects: the safety knowledge module, the safety training module, and the on-site safety management module. Therefore, the web prototype in this study also needs the following three features to improve the health and safety of migrant workers.

1) The web prototype should offer the existing local safety policies to enhance their safety knowledge.
2) The web prototype should include safety training functions to equip migrant workers with the skills to apply their safety knowledge effectively in real projects.
3) The web prototype should incorporate safety management functions to improve on-site safety and reduce the risk of safety incidents during construction.

According to the theoretical guidance and framework model, this web prototype contained the following three sections: (1) Health and safety policy, (2) Safety training, and (3) On-site safety management. The significance and contents of each section are illustrated below. Additionally, based on Wix, these initial contents constitute the foundation of the web prototype's first version (shown in 'dix 2) and serve as a starting point for subsequent improvement experiments.

2.2.1.1. Section 1. Health and safety policy. Inadequate knowledge of safety policies can negatively impact the health and safety of migrant construction workers (Dutta, 2017, Ibarra-Mejía et al., 2021). For instance, some construction companies may resort to intimidating tactics like threatening dismissal or deportation to force migrant workers to comply with unfair safety policies or informal rules, such as unpaid overtime or refusal to claim for work-related injuries (Ibarra-Mejía et al., 2021). A lack of knowledge about local legislations in the host country, such as construction safety regulations or compensation regulations, is one of the influencing factors for the health and safety of migrant

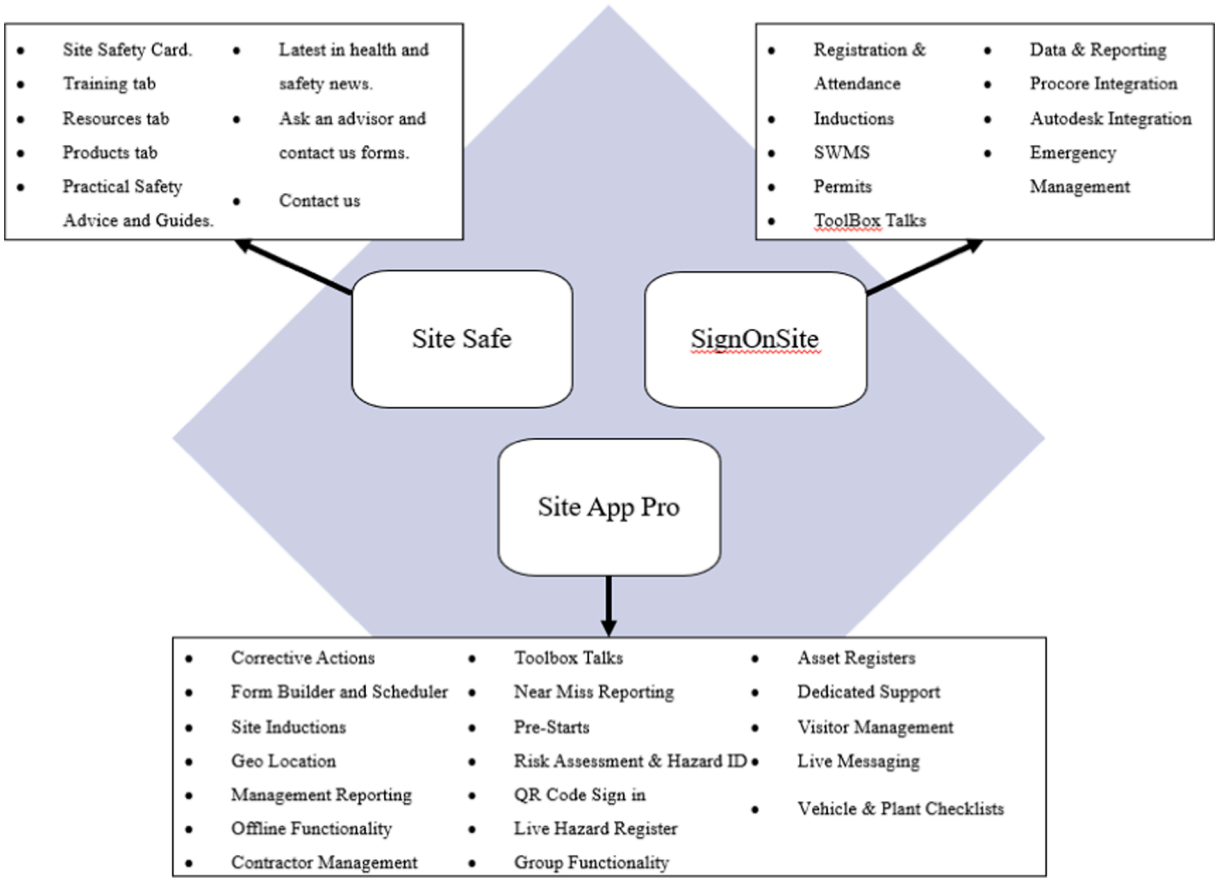


Fig. 2. Review results of different web-based safety management platforms in the New Zealand construction industry (, Site . Source from (Site Safe, 2023b; Signonsite, 2023App, 2023))

construction workers, which hinders their incapacity to safeguard their rights to safety effectively (Lay et al., 2018, Orrenius and Zavodny, 2009). The Health and Safety at Work Act (HSW Act) is the primary official safety policy for reducing workplace injuries in the New Zealand construction industry (Site Safe, 2020). Therefore, the HSW Act is incorporated into the health and safety policy section in this web prototype, allowing respondents to inquire about the safety legislation in the New Zealand construction industry.

2.2.1.2. Section 2. Safety training. Safety training is regarded as an effective strategy to improve the safety behaviours of migrant construction workers (Dong and Platner, 2004, Chan et al., 2016). There are various forms of safety training in practical construction platforms, such as the "Training tab" and "ToolBox Talks". Effective safety training can enhance the practical application ability of migrant workers on actual construction sites (Hussain et al., 2020). The content of safety training should include instruction on safety knowledge, the identification of on-site risks, and the training of professional skills (Mosly and Makki, 2021). In this web prototype, the knowledge points covered in the safety training section are derived from the HSW Act. This section can be divided into three phases: pre-tests, safety knowledge cards, and re-tests. Pre-tests can evaluate the respondents' existing safety knowledge. Subsequently, after receiving the new safety knowledge tutorial through safety training cards, the re-test can assess the ability of training transfer of respondents. The ability of training transfer refers to the ability of trainees to apply the knowledge gained from safety training effectively in actual construction projects (Hussain et al., 2020).

2.2.1.3. Section 3. On-site safety management. In Fig. 2, the most significant contribution of a web-based safety management platform is to strengthen on-site safety management. Establishing a complete on-site safety management system is an intricate process for the web-based safety management platform (Hasan and Jha, 2013). Several features, including "Practical Safety Advice and Guides", "Data & Reporting", "Management Reporting", and so forth, are in place to clarify the safety responsibilities of clients, construction managers, contractors, and construction workers. Managers can efficiently oversee and monitor construction sites through these safety data reports. Workers' accurate knowledge of the division of safety responsibilities can improve their safety compliance on construction sites (Wang et al., 2021). Hence, this study draws on two features in Fig. 2 as the content in the first version of the safety management section in the prototype, which are "Division of Safety Responsibilities" and "Safety Checklist" respectively. The contents of the "Division of Safety Responsibilities" and "Safety Checklist" are shown in Appendix 1. These contents can provide Chinese migrant construction workers with a comprehensive understanding of the safety responsibilities of individuals (managers and migrant workers) and show clearer progress in safety inspections.

2.2.2. Web prototype improvements

Based on Fig. 1, the improvement process can be divided into three stages. In stage one, interviewees are asked to propose safety requirements for the web prototype based on their working experiences. In stage two, feedback were sought from participants on the utility of the prototype and criteria were made based on the feedbacks. In stage three, the prototype will be adjusted in line with the modification criteria and additional Chinese migrant construction workers will be invited to reassess the revised version. This iterative process will continue until no further new modification criteria are proposed. The interview questions for participants in the pilot research are shown in Table 1.

Table 1
Interview questions in pilot research.

Items	Question	Reference
Q_1	Do you think this web prototype can improve your health and safety?	(Matti and Zahid, 2024)
Q_2	Do you think the safety policy section will satisfy your safety requirements?	(Matti and Zahid, 2024)
Q_3	Do you think the safety training section will satisfy your safety requirements?	(Vignoli et al., 2021)
Q_4	Do you think the on-site safety management section will satisfy your safety requirements?	(Ebekozien and Aigbavboa, 2021)
Q_5	What other sections do you think are needed to meet your safety requirements?	(open question, none reference)

A total of 10 interviewees participated in the pilot research. The feedback results (shown in Table 2) were the basis for developing modification criteria (shown in Table 3).

Drawing from the feedback results and modification criteria, the web prototype was rectified in the following four aspects to complete the various functions of this web prototype. Firstly, a language conversion button was added in the web prototype to help users switch between the Chinese version (Simplified Chinese, and Traditional Chinese) and the English version independently.

Secondly, in the safety policy section, three safety regulations or manuals were incorporated to supplement the HSW Act in offering legal safety knowledge to Chinese migrant workers in the NZCI. The "Your health and safety rights and responsibilities-Chinese" and "Construction site safety manual-Chinese" are provided by WorkSafe (Worksafe, 2020). Although there is a dedicated section on the WorkSafe official website, many respondents claimed to be unaware of this information. Both documents are presented in the Chinese language and published on the WorkSafe official website, making them suitable for Chinese migrant workers to read and study. "Health and Safety in Employment Regulations 1995" is legislation to reinforce the HSW Act (Southwell, 2022) and further explain the risks and responsibilities of employees, contractors, and members of the public (New Zealand Legislation, 2017). The revised version of the safety policy section is shown in Fig. 3.

Thirdly, with the improvement of the safety policy section, the test questions in the safety training section should also be revised. In the construction industry, various hazards can lead to both fatal and non-fatal accidents (Carter and Smith, 2006). Among these hazards, falls, falling objects, the use of power tools, and hearing loss are regarded as the most common causes of safety-related injuries (Branz, 2021). This web prototype presented practical safety tests related to these hazards to examine interviewees' existing safety knowledge and safety awareness. The quiz questions are shown in Table 4.

Table 2
Feedback on improving the web prototype.

Interviewee	Feedback
I_1	This prototype is very good and is very helpful for improving my safety awareness and knowledge. The disadvantage is that the functions are a bit limited, with only three features. Hope more features can be developed.
$I_{2\text{-}4}$	This prototype should be switched to Chinese and English modes. This function is missing from the current version. Many Chinese workers in New Zealand do not speak English well, which is why they only choose to work in Chinese companies. This should be noted when designing prototypes.
I_5	In the safety policy section, the HSW Act alone is not enough. The HSW Act regulate general safety standards for all industry in New Zealand. The prototype needs more specific safety regulations for the construction industry.
I_6	I don't think these sections can engage Chinese workers to participate. Researchers need to add more sections to motivate Chinese workers to use this prototype.
$I_{7,8}$	In the safety training section, researchers should add more training on specific safety operations in the construction.
$I_{9,10}$	In the safety policy section, the HSW Act is still in English. This will be difficult for Chinese workers to read. They won't have the patience to read the entire Act. More workers will just follow what managers tell them about legal norms.

Table 3
Criteria and modification of the web prototype.

Criteria	Modification
The web prototype should have Chinese-English conversion function.	Change the web prototype to Chinese and English versions and allow users to switch between the two versions using a language conversion button.
Add more safety legislation in safety policy section.	This web prototype adds three more legislations in the safety policy section, which are "Your health and safety rights and responsibilities-Chinese", "Construction site safety manual-Chinese", and "Health and Safety in Employment Regulations 1995".
Add specific safety construction training items based on the legislation and Act.	Added knowledge points and training questions on working at height, use of safety equipment, use of power tools, hearing protection, and dust.
Add another section to motivate Chinese migrant workers to use this web prototype (Zulkefli et al., 2014).	Added safety incentive section to motivate Chinese migrant workers to use this web prototype through positive safety incentives like reputation and bonus.

Finally, a safety incentive section was added to motivate more Chinese migrant workers to use this web prototype. Safety incentive strategies are seen as a common method to motivate construction workers (Zulkefli et al., 2014). The forms of safety incentives are diverse in practical construction such as financial incentives and non-financial incentives (Hasan and Jha, 2013). Financial rewards or penalties are the safety incentives that exert the most influence on the safety compliance of Chinese migrant construction workers as their primary objective is to earn more money (Zhang et al., 2022). In the safety incentive section, Chinese migrant workers will receive scores corresponding to their performance in the "safety training section" and "on-site safety management section". The top three Chinese migrant workers with the highest scores will be awarded reputations and bonuses. The content of this section is shown in Fig. 4.

The reliability of this web prototype was validated through both a pilot study and a formal study. In the pilot study, 15 industry professionals participated in an iterative improvement process, which involved a continuous cycle of feedback, modifications, the establishment of new criteria, and the development of updated models. This process ensured that the prototype was refined and adjusted based on expert input to enhance its effectiveness and reliability. Following the iterative improvement process, the next five consecutive respondents agreed that the prototype met all of their requirements and did not suggest any further modifications. This consensus marked the completion of the refinement phase and confirmed the prototype's readiness for the subsequent stages of the research. Therefore, this version can be regarded as the final version and commenced semi-structured interview surveys. The final version of the web prototype is shown in Appendix 3.

2.3. Interviews based on the final version of the web prototype

In the semi-structured interview surveys, 22 Chinese migrant workers visited the final version of the web prototype. Respondents were asked about the effectiveness of the web prototype in enhancing the health and safety of Chinese migrant workers. The interview questions are shown in Table 5. A critical analysis was conducted to assess the effectiveness of the web prototype based on the interview results.

3. Results

In this study, 22 respondents participated in the evaluation of the final version of the web prototype through semi-structured interview

Fig. 3. Comparison of initial and final versions of the safety policy section.

surveys. This section not only showed the feedback from respondents on the effectiveness analysis of the web prototype but also presented the outcomes of the two safety training tests in which the respondents participated. The detailed results for each stage are shown below.

3.1. Quantitative results

The first question aimed to ascertain the safety policies implemented by the respondents' companies. The results of Q1 are shown in Table 6.

All respondents expressed their companies' commitment to providing a safe workplace, safety equipment, and safety training. 64 % of respondents stated that their companies were dedicated to minimizing on-site injuries. 73 % of respondents demonstrated that their companies fostered positive communication to improve the health and safety of Chinese migrant workers.

Q2 to Q8 encompass practical site safety knowledge related to falls, falling objects, the use of power tools, and hearing loss. The results of the safety training in "Pre-tests" and "Re-tests" are shown in Fig. 5 and Fig. 6. Fig. 5 shows the percentage of respondents who answered correctly across the two tests and Fig. 6 illustrates the accuracy of each question in the two tests.

The quantitative results showed that in the pre-test, only 5 % of the respondents (1 individual) were able to correctly answer all test questions related to safety regulations and on-site practical skills knowledge. 32 % of all respondents (7 individuals) could only answer 3 questions correctly. Respondents who only answered one or two questions correctly accounted for 22 % of all respondents, with five individuals respectively. After the safety training sections in this web prototype, 46 % of respondents (10 individuals) answered all the training questions correctly in the re-tests, representing a growth rate of 41 %. 27 % of respondents (6 individuals) provided an incorrect response to only one question, indicating a growth rate of 27 %. All respondents demonstrated proficiency in answering more than 4 test questions correctly (totalling 7 questions).

3.2. Qualitative results

The aim of the semi-structured interview is to explore the respondents' suggestions for the effectiveness of the web prototype for the health and safety improvement of Chinese migrant construction workers. While most of the respondents (16 individuals) recognized this web prototype, 6 of them had doubts regarding the effectiveness and feasibility of the web prototype in improving the health and safety of Chinese migrant construction workers.

3.2.1. Positive qualitative feedback

Respondents highlighted that this web prototype can contribute to improving the health and safety of Chinese migrant construction workers. This web prototype contains safety policy knowledge and practical safety manuals, which encompass essential knowledge points that Chinese migrant construction workers should be proficient in.

> *"Many Chinese workers cannot read the English version of safety policies. This prototype, definitely, helped improve their safety knowledge." (P3, P5, P6).*
> *"What Chinese migrant construction workers often lack is not skills but knowledge. Many of them do not know the local laws and thus they are unable to safeguard their rights to safety." (P10, P12, P19).*
> *"Many Chinese workers come to new countries, but they are not familiar with local safety regulations. They want to know relevant legal knowledge but many times they do not know where to get the corresponding knowledge." (P4, P18).*

Some respondents demonstrated that the safety training section in the web prototype can not only help Chinese migrant workers effectively consolidate their existing safety knowledge but also enhance their safety awareness.

> *"Safety training is necessary. It's good to take the quiz to make me rethink about these H&S clauses which I took for granted." (P1).*
> *"Efficient. I think the Chinese and English versions of the test helped me better understand the test questions. Plus, this form of quiz solidifies my knowledge and tells me what I should pay attention to in the venue." (P3, P16, P22).*
> *"Yes, I think this training can effectively increase prevention awareness." (P14).*

Furthermore, compared existing platform, the inclusion of the safety incentive section is a novel feature of this web prototype. Many respondents also gave positive recognition to this section.

> *"This is an interesting section for a web-based safety management platform. Typically, a company doesn't pay much attention to incentives because it is hard to implement incentives, especially financial incentives effectively." (P7, P10, P13).*
> *"Absolutely feasible. Chinese migrant workers tend to prioritize financial incentives, such as bonuses, wage increases, and rewards." (P15, P16, P18, P19).*

Table 4
Quiz questions in the safety training section.

Items	Safety training quiz	Multiple Options
Q1	What does the company's health and safety policy include?	a) Provide a safe workplace, safe equipment, appropriate PPE and insist on safe work practices at all times, for both employees and subcontractors. Working together to eliminate on-site injury. Providing effective safety training. Encourage open communication and a "just culture" attitude to Health and safety.
Q2	Which of the following is true about a worker's right to cease or refuse to perform unsafe work?	a) A worker may cease, or refuse to carry out, work if the worker believes that carrying out the work would expose the worker, or any other person, to a serious risk to the worker's or other person's health or safety arising from an immediate or imminent exposure to a hazard. b) A worker can refuse to work without explaining the situation to a supervisor. c) A worker can refuse to do work that, because of its nature, inherently or usually carries an understood risk to the worker's health and safety. d) Workers are free to refuse all works.
Q3	Which of the following options are your rights when you encounter risks?	a) Discuss your concerns with your employer, manager, or safety manager. b) Refuse the work without any discussion with the supervisor. c) Report to the relevant agency or authority. d) Refuse the work that has inherent risks or the work that all practicable steps have been taken to prevent harm from that hazard.
Q4	Which of the following are the responsibilities of workers at work?	a) Take reasonable care for his or her own health and safety. b) Take reasonable care that his or her acts or omissions do not adversely affect the health and safety of other persons. c) Comply, as far as the worker is reasonably able, with any reasonable instruction that is given by the PCBU. d) Co-operate with any reasonable policy or procedure of the PCBU relating to health or safety at the workplace that has been notified to workers.
Q5	Which of the following options need to be considered when working on a roof?	a) Consider the location and provision of anchorage points for safety harness systems or safety nets. b) Prepare the area below the roof to provide a firm and level support for mobile elevating equipment such as a scissor lift or cherry picker. c) Provide a guardrail around the perimeter. d) Consider providing permanent access and edge guard railing to the roof.
Q6	Which of the following options are the functions of hard hats?	a) Against being hit or struck by falling, fixed, moving or protruding objects. b) Against falling from the heights. c) Against coming in contact with electricity. d) Against to be exposed to UV, weather, and extremes of temperature.
Q7	Which of the following options is false about electrical equipment?	a) Consider all electrical wires and equipment live until they are tested and proven otherwise. b) Inspect cords, plugs and electrical equipment before each use. Repair or replace damaged equipment immediately. c) Use outlets or cords that have exposed wiring. d) Use ladders made with non-conductive materials (e.g., fiberglass).
Q8	Which of the following options can prevent noise-induced hearing loss?	a) Wear proper hearing protection (earmuffs or plugs) in noisy environments or when doing noisy jobs. b) Choose protection that fits and feels comfortable for long periods of wear. c) When you could bear the noise conditions, you could not wear hearing protection. d) Keep tools and equipment maintained – some equipment is noisier when not kept in good order.

"If the company is willing to add incentive mechanisms in the web-based safety management platform, many Chinese construction workers will actively participate in the web-based safety management platform. The prospect of earning additional income, coupled with the opportunity to acquire safety knowledge, is anticipated to bring considerable satisfaction to the workers." (P21, P22).

All the respondents illustrated that the bilingual version of the web prototype served as a significant feature in assisting Chinese migrant construction workers in acquiring safety knowledge and comprehending on-site safety management.

"I really like this Chinese version of the web prototype. Many construction platforms in New Zealand are available only in English. This is not conducive to some Chinese workers whose English is not good. The Chinese version of the web-based safety management platform is easier for most Chinese workers to operate." (All participants).

3.2.2. Negative qualitative feedback

While many respondents acknowledged the effectiveness of the web prototype in improving the health and safety of Chinese migrant workers, a significant number also expressed doubts about its effectiveness in practical projects. Opponents pointed out that in actual projects, Chinese migrant construction workers had a low level of safety awareness, which resulted in weak participation in web-based safety management platforms. The limited participation of Chinese migrant construction workers significantly reduced the effectiveness of the knowledge-based safety web prototype.

"Many Chinese workers have low safety awareness. They only care about their income and working hours. As long as the company gives them a lot of money, they don't care about safety." (P2).
"Chinese migrant workers often lack the initiative to utilize web-based safety management platforms. Their strenuous work at the construction site leaves them fatigued, making it nearly impractical to anticipate them studying during breaks." (P8, P9).

Fig. 4. Web capture of the safety incentive section.

Table 5
Interview questions in formal experiments.

Items	Question	References
Question 1	Please share your opinion on the main challenges and opportunities of this web prototype in enhancing your health and safety.	(Matti and Zahid, 2024)
Question 2	In what specific way do you think this web prototype improves your health and safety? (such as improvements in safety awareness, safety behaviour, safety knowledge, etc.)	(Park and Kim, 2013)
Question 3	Do you think this web prototype can effectively improve the health and safety of Chinese migrant workers in actual construction projects?	(Matti and Zahid, 2024)

Table 6
The results of Q1.

Options in Q1	Respondents	Frequency / (out of 22 respondents), %
a) Provide a safe workplace, safe equipment, appropriate PPE and insist on safe work practices at all times, for both employees and subcontractors.	22	100 %
b) Working together to eliminate on-site injury.	14	64 %
c) Providing effective safety training.	22	100 %
d) Encourage open communication and a "just culture" attitude to Health and safety.	16	73 %

"In their view, what is important is the arrangement of the on-site managers or supervisors. They don't need to visit web-based safety management platforms. They just need to work as directed by their managers." (P20).

"I am too tired every day and do not have extra energy or time to visit this prototype. Unless my company gives me an extra salary or vacation." (P11).

Two opponents questioned the effectiveness of the safety training section in this web prototype. In their opinion, the number of safety test questions is one of the factors affecting the effectiveness of the safety training section in the web prototype. Insufficient test questions may not yield the training effect, while an excessive number of test questions may reduce completion rates and overall participation.

"Insufficient questions may hinder the training effectiveness, while too many questions will discourage Chinese migrant workers participants from continuing." (P2, P11).

On the other hand, the safety awareness of employers or supervisors of Chinese migrant workers also directly impacts the effectiveness of web-based safety management platforms. As construction team supervisors, three respondents (P9, P17, P20) stated that supervisors often prioritize assessing whether workers can complete safety training courses and pass safety training tests provided by government agencies, without necessarily focusing on whether Chinese migrant workers can master safety knowledge. Construction supervisors focused more on the certificate in safety training courses. Moreover, respondents also questioned whether the web prototype can bring profits to construction companies. One participant (P20) insisted that sufficient financial support was a vital resource for maintaining the effective operation of the web-based safety management platform.

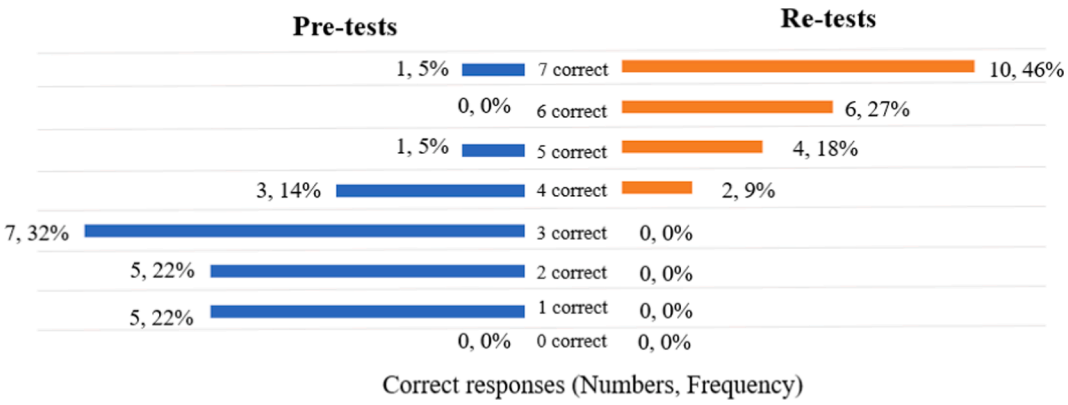


Fig. 5. Number and proportion of correct responses for all questions.

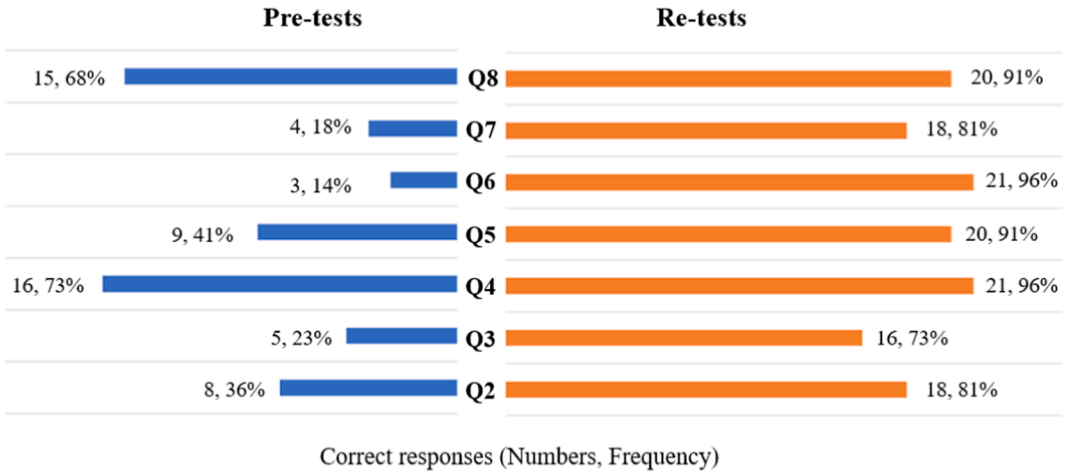


Fig. 6. Number and proportion of correct responses for each question.

"When workers complete a safety training course, like the course arranged by Site Safe, they will receive a certificate of completion indicating they are ready to work…. The key point is the certificate, as long as they have the certificate, I will hire them." (P17).

"This prototype uses incentives to motivate Chinese workers to participate in the platform, but how to ensure the interests of the company? Companies or managers are not willing to pay for this cost." (P9, P20).

"How will your platform make money, and how will you ensure that your prototype operates effectively? This is the key factor you should consider. I suggest that you can expand from two aspects: charging advertising fees or government subsidies." (P20).

4. Discussion

This study employed Chinese migrant construction workers in New Zealand as a case study to investigate the effectiveness of web-based safety management platforms in improving the health and safety of migrant construction workers. A total of 37 professional Chinese migrant construction workers participated, with 15 involved in the pilot study and 22 in the formal study. Based on their extensive professional experience in the construction industry, respondents provided in-depth analysis and constructive feedback on the web prototype, which supported the verification and refinement of this experiment. These insights were rigorously compared, analysed, and reintegrated through an iterative process, thereby providing robust data support for both the qualitative and quantitative components of the research. The results of both qualitative and quantitative data analyses confirmed the effectiveness and feasibility of the web prototype for enhancing safety management among Chinese migrant construction workers in actual construction projects.

Compared with other web-based safety management platforms, this web prototype adopted both Chinese and English to decrease the negative effects of language barriers for Chinese migrant workers. Language barriers have consistently been regarded as a significant factor affecting the health and safety of migrant construction workers (Kim et al., 2020). All interviewees highlighted that language barriers are a common challenge for numerous Chinese migrant construction workers. However, a shared language and cultural environment can reduce safety hazards for migrant workers on construction sites (Roelofs et al., 2011). Hence, compared with obstacles in communication, the impact of language barriers on migrant construction workers is more likely to hinder the acquisition of safety knowledge and safety information. For instance, due to language barriers, it can be challenging for migrant construction workers to independently access compensation information, and the acquired information may also contain misunderstandings or disinformation (Premji et al., 2023). This web prototype provided bilingual safety information and knowledge to respondents, which earned substantial support from numerous Chinese migrant construction workers. Consequently, the provision of bilingual web-based safety management platforms and multilingual safety regulations proves to be an effective strategy for improving the active participation of migrant construction workers in web-based safety management platforms.

Safety training is a long-term process for enhancing the safety awareness and conduct of construction workers (Nielsen et al., 2023). Three interviewees demonstrated that Chinese migrant workers are required to participate in the safety training courses by Site Safe (a New

Zealand government organization) and to obtain safety certificates. In New Zealand, construction workers need a New Zealand Qualification Authority-recognised New Zealand Certificate in Workplace Health and Safety Practice (Level 3) before working (Site Safe, 2021). However, the results of this study indicated that obtaining a safety certificate is not a reliable indicator of comprehensive safety knowledge among Chinese migrant construction workers. For instance, despite all respondents indicating that they have undergone safety training courses, their average correct rate in the safety pre-test in the web prototype is only approximately 38.96 %. This phenomenon is affected by both construction organizations and individuals. On the one hand, construction organizations relied more on safety certificates instead of the ability of safety training transfer (Nielsen et al., 2023). On the other hand, due to the lack of bilingual safety training, migrant construction workers may misunderstand or confuse safety knowledge points (Guan et al., 2024). Some skilled Chinese migrant construction workers may be overconfident in their experience to neglect the importance of safety training. The effectiveness of safety training is affected by the frequency and duration of training (Burke et al., 2006). The test accuracy rate of Chinese migrant construction workers increased significantly to 87.01 % after taking the small-scale safety training. Hence, companies should increase the frequency of safety training to improve the accuracy of safety knowledge and education. It is worth noting that some respondents indicated that the number of training questions and the frequency of safety training should be dynamically adjusted based on the actual conditions of the construction project. This necessitates that safety managers effectively balance the relationship between work progress and safety training. As shown in this web prototype, the web-based safety management platform ought to provide daily small-scale safety training to migrant construction workers. This kind of platform can not only decrease the costs of safety training but also fundamentally elevate safety awareness and education level proficiency among migrant construction workers.

This web prototype may confront potential challenges during the implementation phase in practical construction projects. On the one hand, Chinese migrant construction workers are unlikely to spend their personal time browsing or using web-based safety management platforms, attributing this reluctance to a lack of safety awareness and motivation. On the other hand, it is necessary to assess the feasibility of the web prototype in generating financial benefits for construction companies. This study proposed the following two strategies to address these challenges. Firstly, the web prototype added a safety incentive section to motivate migrant construction workers to participate in the web-based safety management platform. The primary objective of migrant workers is to gain financial benefits (Afuye et al., 2022). The interview results show that safety incentives, especially financial incentives, can significantly increase the involvement of Chinese migrant construction workers. Construction companies can motivate migrant construction workers' safety performance with positive or negative incentives (Wei et al., 2012) such as bonuses (Abas et al., 2020), promotions (Hasan and Jha, 2013) or fines (Afuye et al., 2022). However, construction workers may conceal or provide false information about safety incidents to obtain high financial benefits (Kim et al., 2019). Hence, this study suggests the use of small-scale, multiple-time financial and non-financial safety incentives to motivate migrant construction workers to actively engage with web-based safety management platforms.

Extensive data from existing literature highlight the critical role that safety management platforms play in improving safety practices within the construction industry. Building on this foundation, this web prototype developed in this study utilises insights from the literature review and existing applications as a template. It introduces key optimizations and enhancements, incorporating numerous practical features specifically designed to address the unique safety needs of Chinese migrant construction workers. For instance, this research explored various approaches for web-based safety management platforms based on preliminary literature review— enhancing safety regulations (Lu et al., 2015), safety training (Eiris et al., 2020), and safety incentive programs (Guo et al., 2018)—to comprehensively improve the health and safety of Chinese migrant construction workers.

5. Implication

This study has the following two contributions. Firstly, this study contributes to enhancing the overall safety management standards within the construction industry while also addressing the existing research gap in the field of safety management. A substantial body of literature has examined the effectiveness of web-based safety management platform tools in enhancing safety management within the construction industry (Shayesteh et al., 2023; Liu and Tian, 2019; Bao et al., 2022). Many of these studies employ prototypes to achieve their objectives related to safety management (Zou et al., 2017). The prototype developed in this study represents a targeted health and safety solution for Chinese migrant construction workers in New Zealand. Migrant construction workers face unique safety challenges compared to the native workforce, including language barriers, limited safety awareness, insufficient safety training, and the need for stronger incentives (Guan et al., 2024, Vignoli et al., 2021). Drawing on a preliminary literature review and semi-structured interviews, this study utilised Chinese migrant construction workers in New Zealand as a case study to address the research gap in the field of safety management platform tools for migrant construction workers by providing substantial literature, offering data support, and contributing to the establishment of a theoretical model.

Secondly, this study developed a novel web prototype for examining the challenges associated with the application of web-based safety management platforms among Chinese migrant construction workers. The creation of this web prototype contributes to the design and evaluation of the existing technological web-based safety management platform. This research utilized this web prototype as a model to explore the generalisable conclusions of the effectiveness of web-based safety management platforms in enhancing the safety of migrant construction workers. Future research on the safety challenges faced by Chinese migrant construction workers in other countries and the safety challenges of migrant construction workers of various nationalities can refer to this web prototype as a foundation model to conduct further explorations.

6. Conclusion

Based on existing literature and practical application tools, this study developed a web-based safety management prototype specifically designed for Chinese migrant construction workers. Although existing literature has extensively explored the application of safety management platforms in the construction industry, there remains a notable research gap in comprehensive and systematic in-depth analyses focusing specifically on migrant construction workers. The prototype enhanced traditional safety management platforms by incorporating safety mechanisms and features tailored to the unique challenges faced by Chinese migrant construction workers. The novel web prototype was designed to motivate and enhance safety awareness, knowledge, and compliance among Chinese migrant construction workers, which can strengthen the management capabilities of existing safety management platform tools. This web prototype serves as a practical solution strategy specifically designed to address the unique safety factors affecting Chinese migrant workers. The web-based system layers were shown in Fig. 7.

Firstly, Chinese migrant construction workers express a desire to acquire safety knowledge about local safety regulations, such as rights protection and compensation. Nevertheless, language barriers significantly affect them in learning and understanding local safety regulations and codes of conduct. The proposed web prototype incorporated

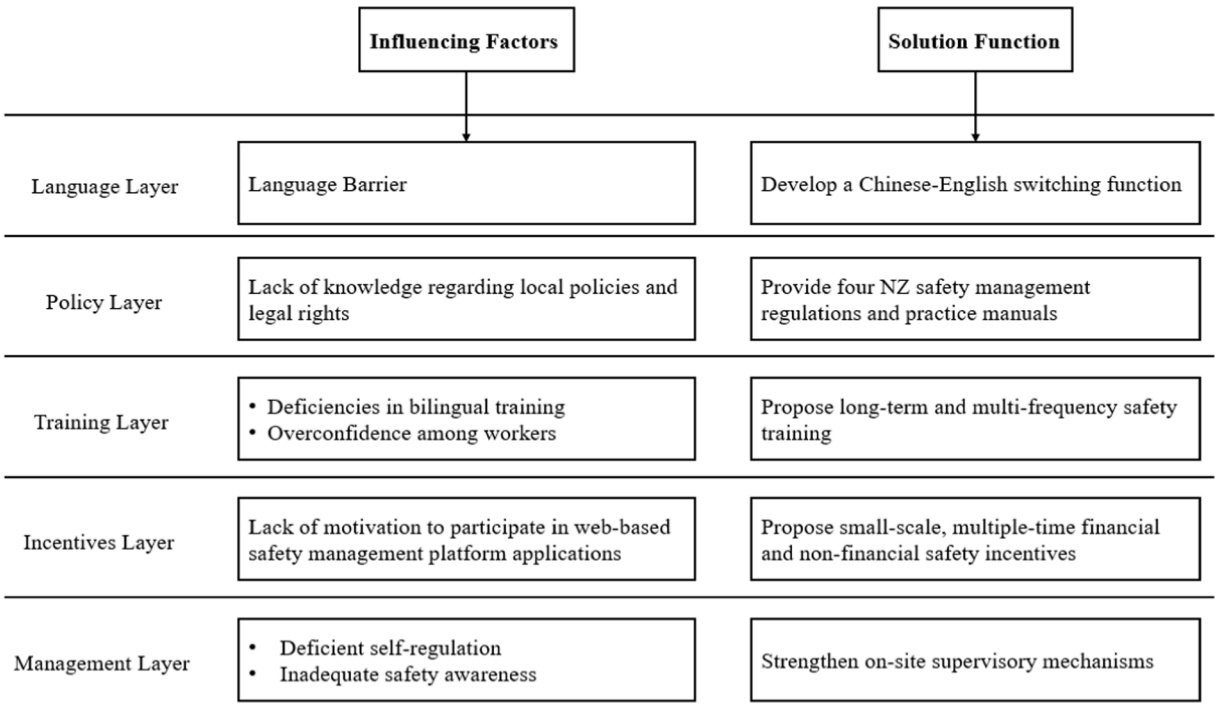


Fig. 7. Web-based safety management prototype layers.

bilingual versions of legal safety policies and practical construction skills to decrease the safety risks affected by language barriers. This approach not only improves the feasibility of learning safety regulations but also increases the interest in safety learning.

Secondly, web-based safety management platforms and safety training have consistently been interconnected in the construction industry. The research results showed that although Chinese migrant construction workers have completed relevant safety training courses, their grasp of safety knowledge remains deficient and inaccurate due to overconfidence or lacking motivation. Hence, this study suggests a hierarchical approach to safety training knowledge and integrates it into the web prototype to achieve long-term and multi-frequency safety training.

Thirdly, this study added a safety incentive section to motivate Chinese migrant construction workers to participate in this web prototype. As for migrant construction workers, safety incentives, especially financial incentives, are the most effective strategy to improve their participation in the web-based safety management platform and safety management. This study suggested using small-scale, multiple-time financial and non-financial safety incentives to ensure the feasibility of implementing safety incentives in the web-based safety management platforms. Moreover, web prototype could offer benefits to construction companies through government financial support or advertising fees to ensure efficient operation, but this research direction still requires further investigation.

Finally, this web prototype strengthens on-site safety management by improving supervision and assessment processes. Through a combination of incentives and passive oversight, migrant construction workers are encouraged to take an active role in site safety management, thereby increasing the efficiency and effectiveness of safety protocols. The participation of construction workers in site safety management is one of the effective strategies for improving the overall safety climate (LÓPez-Jacob et al., 2010).

There are two primary limitations to this study. One of the limitations of this study is geographical restrictions. This study focuses exclusively on Chinese migrant construction workers in New Zealand. Another limitation of this study is the relatively small sample size, which was constrained by the five-month data collection period. While the findings of this research remain reliable and valid, a larger sample size would provide even greater rigor and enhance the generalizability of the conclusions.

Future studies could extend the research timeframe or expand the geographic region to increase the sample size, allowing for a more comprehensive evaluation of the web prototype's effectiveness among Chinese migrant construction workers. Additionally, further research could compile generalized conclusions regarding this web-based safety management prototype across different regions and migrant worker populations to assess its broader applicability. Future research could also explore potential differences in health and safety practices between different workers groups defined by age, gender, education-level, ethnicity, and different job tasks, etc.

CRediT authorship contribution statement

Zechen Guana: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Don Amila Sajeevan Samarasinghe:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Data curation. **Tak Wing Yiu:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Ian Laird:** Writing – review & editing, Validation, Supervision. **Ravi Reddy:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

None

Appendix

Location 位置	Safety manger 安全经理	Safety Responsibility Zone 安全责任区域	Status 状态	Register Person 登记人	Date 登记日期
Area a	XXX	Infrastructuree	Pass	XXX	
Area b	XXX	Interior Construction	Submit	XXX	
Area c	XXX	Site 3	Fail	XXX	

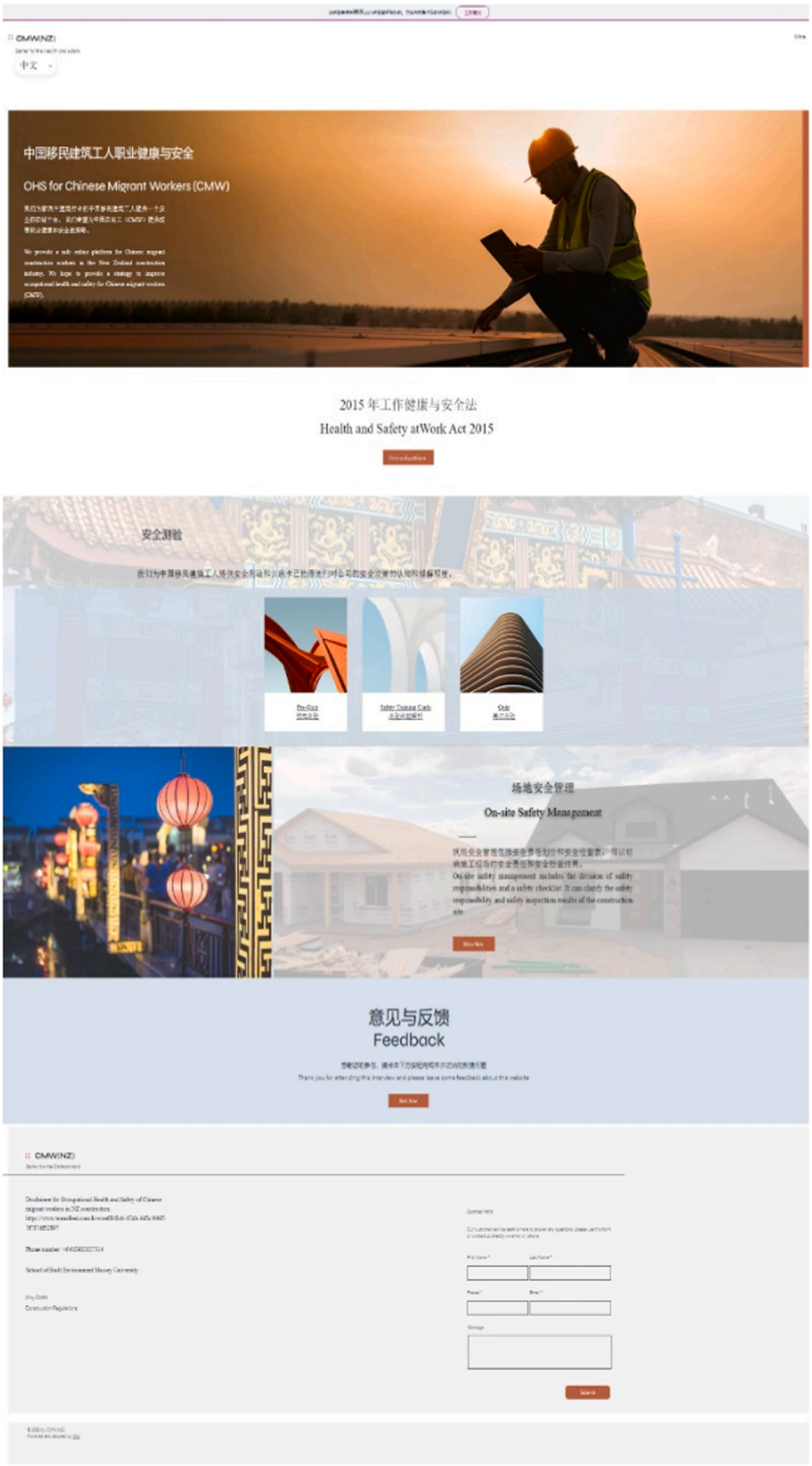
Division of safety responsibilities

Item Number	Inspector	Inspected Location	Date	Result	Status
Item 1	XXX	Site 1	2/03/2022	Qualified	/
Item 2	XXX	Site 2	15/06/2022	Unqualified	Need Rectification

Safety Checklist

.

Appendix 1. . Content of safety management section



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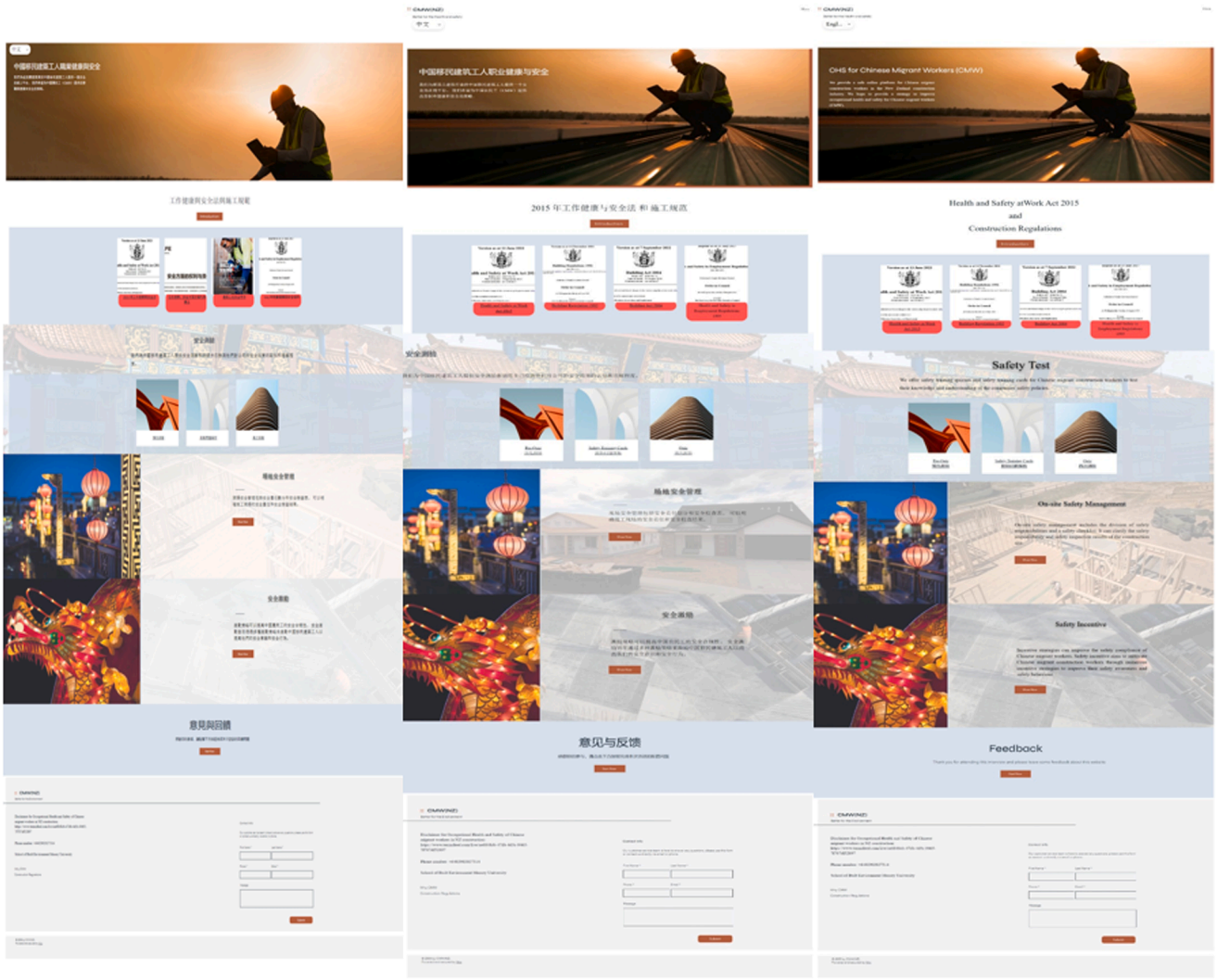
Appendix 2. . Web prototype original version



Appendix 3

Web prototype final version (Left: Traditional Chinese version; Middle: Simple Chinese version; Right: English version)

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